AN EVALUATION OF PASSIVE DESIGN PRINCIPLES IN THE DESIGN OF PROPOSED SHOPPING MALL, ABUJA

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BY

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JULY, 2018

DECLARATION

I declare that the work in the dissertation entitled, "AN EVALUATION OF PASSIVE DESIGN PRINCIPLES IN THE DESIGN OF PROPOSED SHOPPING MALL, ABUJA" has been performed by me in the Department of Architecture under the supervision of Dr. A.J Ango and Arc. S.S Tulpule. The information derived from the literature has duly been acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

David Lawan POGU		**JULY, 2018**
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Name	**Signature**	**Date**

CERTIFICATION

This dissertation entitled "AN EVALUATION OF PASSIVE DESIGN PRINCIPLES IN THE DESIGN OF PROPOSED SHOPPING MALL, ABUJA" by David Lawan POGU meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

The research is dedicated to the Almighty God who made all things possible through His Grace and to my parents Mr and Mrs Pogu Lawan & family.

ACKNOLEDGEMENT

My profound appreciation goes to God Almighty, the author of life for granting me the opportunity to complete my studies. Words are not enough to express the magnitude of joy that I feel inside of my heart, but all I can say is thank you Lord. I will like to acknowledge my supervisors Dr. A.J Ango, and Arc. S.S. Tulpule for guiding me in this research work tirelessly.

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ABSTRACT

Buildings are responsible for at least 40% of energy used in most countries, in Nigeria construction activities has pervaded most urban centres as in the case of Abuja. Evaluating passive design principles in buildings is the clever way in designing energy efficient building that will be peculiar to the local climate of a region. Most shopping malls in Nigeria use mechanical system of cooling and lighting which increases its operational cost, because proper passive design principles have not been integrated into the building. This study identifies and evaluates different passive design principles that will reduce building operational cost. Literature on passive principles were studied in which the passive design features in buildings were identified and examined in various ways that can help in reducing building operational energy demands. The research methodology adopted was a case study approach, experimentation, visual survey of various passive design features applied on the case study buildings. Qualitative data collections were adopted through visual field survey, interview, checklist, photographs, sketches, notes, as instrument of data collection. Case studies of relevant shopping malls were analysed using variables such as site analysis, building form, building orientation, landscaping, external wall, thermal insulation, roofs and windows. Ceddi Plaza Abuja and Silverbird Entertainment Centre Abuja (i.e case study 1 and 2) were modelled and analysed with the aid of Autodesk Ecotect analysis software. The simulation conducted are base on the assumptions established for zones in the analysis of energy consumption for case 1 and 2 to determine the annual operational energy demand of the buildings, using weather data collected from Abuja metrological agency. Case studies 1 and 2 have the total annual operational energy consumption of 192.497kwh per square meter and 164.134kwh per square meter respectively. The various material properties used in the modelled building under

observation were altered in terms their “u-values”, it was observed that the proposed shopping mall design indicate a decrease in the annual operational energy demand by 36.3% and 24.3% with respect to case study 1 and 2. Therefore building simulation and investigating the performance of the building virtually in the pre-construction stage will help architects and other consultants to apply suitable passive design principles that will suit a particular local climate and reduces the building annual operational energy demand.

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CHAPTER ONE

1.0 Introduction

As shopping malls space becomes more multi-use, the spaces provided should adapt to the need of the users. This dissertation tends to evaluate the principles of passive design in the design of a shopping mall in order to reduce its annual energy demand especially in hot-humid climate of Nigeria.

1.1 Background of Study

Twenty years ago, a historic meeting of governments, business organisations and civil society organisations laid down an obligation to achieve sustainable development, named the Rio Declaration. This phenomenal declaration by the United Nations General Assembly as cited in Miyazawa (2012) brought in its wings, as a fundamental paradigm that embraced the integration of economic growth, social equality and environmental sustainability. However, there still remains a gap between this declaration and fruitful action. While the landmark definition of Sustainable development presents it as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Therefore the necessity for passive design in both developed and developing countries is fast assuming an important global stance.

Abreu (2012) called for global sustainability where all countries commit to sustainable development and the "greening" of their economic systems with clean technology, innovation, and sound science. According Abreu (2012), for the proposed sustainable development goals to be effective, there should be a call for international scientific cooperation and coordinated research on major passive design challenges, building on, and working with existing programs. Here, among other disciplines, architecture finds a striking

relevance. The primary role of the Architect is to create places from existing spaces. In doing this, he must ensure he factors in sustainability values. The goal of passive design is to improve living standards and the quality of people's lives, both now and for future generations. Since architecture relates with the environment, it is therefore important that the protection of such environment should be paramount in the conceptual developments of the architect.

Architecture is the art and science of building (Ijatuyi & Arayela, 2013). The architect as a spatial planner is saddled with the responsibility of creating sustainable spaces through sustainable means. Furthermore, the building is the architect's creative work and it is the microcosm of the larger environment, both of which must be sustainably handled. In view of this, the duty of the architect within the environment is to do his part by ensuring sustainable architecture within a sustainable environment. Roux and Alexander (2007) state that "careful selection of environmentally sustainable building materials is the easiest way for architects to begin incorporating passive design principles in buildings". It is worthy of note that the erection of building structures, however small, involves several activities that have negative impact on the environment if sustainable measures are not considered, which results in 50% of all carbon dioxide emissions worldwide Roux and Alexander (2007). Right from the conceptual design stage to its erection, the impact of these activities on the environment should be checked. Therefore, the architect has the responsibility of ensuring sustainability in his designs. Having been aware of the adverse effects of building construction on the environment, various concepts guiding passive design have evolved; among these are sustainable architecture and green or sustainable construction.

Shopping malls have been developed everywhere with trends like theme parks, sport arenas, indoor leisure sites, centre parks, multiplex cinemas and or musical theatres. These centres, often dedicated to a special theme, combine different leisure functions with retail trade and entertainment. Because of their huge size, growing number and needful catchment areas, their spatial impacts are immense. Reducing the consumption of electricity in shopping malls is very important especially on air conditioning and lighting systems.

1.2 Problem Statement

Buildings are responsible for at least 40% of energy used in most countries (Roux & Alexander, 2007). The absolute figure is rising fast as construction booms, especially in counties such as China and India (Roux & Alexander, 2007). It is essential to act now, because buildings can make major contribution to climate change and energy use. Olotuah (2009) opined that incremental construction has pervaded most urban centres in Nigeria. Many of such buildings are inhabited with the barest facility in place. Although sustainability is fast assuming a global trend, the position of architecture in actualizing passive design goals in developing countries is not encouraging. In recent times, most buildings design in Nigeria trend towards mix-use functions as in the case of shopping malls where shopping, entertainment and recreation fall under the same roof. As a result of that, high energy demand which has not been adequately met since the country faces constant power disruption due to insufficient supply of power (Malgwi & Sagada, 2014). On the other hand, most shopping malls in Nigeria fulfil this cooling requirement with the help of air conditioning and cooling units which are not sustainable in terms of energy efficiency (Malgwi & Sagada, 2014).

1.3 Justification of Study

The climate as a substantial part of the environment faces changes over time. Now the serious risks of these changes to global sustainable development are indisputable, but most times, attention is mainly on the problems and not the solutions (Murdoch, 2006). Many research effort on the necessity for energy buildings abound. Despite its acclaimed vagueness and ambiguity, the World Commission on Environment and Development (WCED, 2000) definition of sustainable development has been highly instrumental in developing a "global view" with respect to our planet's future. Since then, thousands of initiatives have been taken at local, national and global levels in an attempt to address different aspect of environment challenges. However, most of these initiatives are yet to meet the needed and significant global goals especially in developing countries of the world. High internal temperatures in hot season and low in cold season are not only working against an efficient use of energy, but generate thermal shocks instead of providing opportunity for the human body to adapt. It is therefore important to evaluate those passive design principles applied on shopping malls in Abuja and proposed an energy efficient and sustainable shopping mall with the aim of reducing it operational energy demand.

1.4 Aim and Objectives

The aim of this study is to explore the promotion of passive design principles and effectively integrates passive design elements into a shopping mall design scheme in order to reduce shopping mall annual operational energy demand.

This will be achieved through the following objectives:

i. To establish those passive design principles fitting for shopping mall.
ii. To identify architectural features that will reduce shopping mall annual operational energy demand.

iii. To demonstrate findings in the design of a shopping mall in Abuja.

1.5 Research Questions

i. Which passive design principles are applicable to shopping malls for the reduction of energy consumption?

ii. How to integrate those passive design principles in a shopping mall design scheme to reduce its annual operational energy demand?

1.6 Scope and Limitation of the Study

The research is limited to the application of those passive design features in the design of a shopping malls, specifically, in a hot-humid climate of Nigeria. It highlights the theoretical framework necessary to reduce the annual operational energy demand in the design of a shopping mall through the assessment of existing principles and the consideration of the study area climate. Therefore, (Jones, 1998) has concluded that energy use in modern buildings occur in five phases, namely, manufacture of building materials, transportation of building materials to the site, on-site construction activities, the operational phase, (running of the building) and finally, the demolition process of buildings and recycling of building materials. This study confined itself in considering energy use at the operational phase of the building. Therefore, this research is geared to develop theoretical solutions as well as design solutions through passive design approach in order to reduce the annual operational energy demand in shopping mall design within the hot-humid climate of Nigeria.

CHAPTER TWO:

2.0. Literature Review

2.1 Passive Design

Passive Design regards the particular way to construct a building using the natural movement of heat and air, passive solar gain and cooling in order to maintain a good internal comfort. Through the use of passive solutions it is possible to eliminate, or at least reduce, the use of mechanical systems and the energy demand by 80% as well as the CO2 emissions.

Building a passive house takes careful planning, which includes the introduction of five basic principles:

- Orientation
- Overhangs and shadings
- Insulation
- Double or triple glazing
- Thermal mass (Passive Design Theory, 2015)

2.1.1 The Core Principles of Passive Design for Building in the Tropics

• Avoid heat gain

- Orient the building to reduce exposure to midday sun, particularly summer sun.
- Use materials with low thermal mass (as a general rule).
- Shade walls and windows, particularly any walls with high thermal mass.

- Use double glazing on windows that cannot be effectively shaded.
- Use insulation, light colours and heat reflective surfaces (Cairns Reginal Council, 2011).

• Encourage natural ventilation

- Orient the building and windows towards prevailing easterly winds.
- Include open able windows and ceiling vents that enable the building to naturally ventilate (Cairns Reginal Council, 2011).

• Make use of natural light

- Install shaded windows.
- Install shaded skylights, light tubes and other natural lighting devices (Cairns Reginal Council, 2011).

• Create cool outdoor areas

- Use verandas and deep balconies to shade and cool incoming air.
- Use landscaping to provide shade without blocking cooling breezes and use planting to reduce ground temperature and minimize reflected heat (Cairns Reginal Council, 2011).

2.1.2 Key Features of Passive Design

The key elements of passive design are: building location and orientation on the site; building layout; window design; insulation (including window insulation); thermal mass; shading; and ventilation. Each of these elements works with others to achieve comfortable temperatures and good indoor air quality (Branz , 2015).

The first step is to achieve the right amount of solar access enough to provide warmth during cooler months but prevent overheating in summer. This is done through a combination of location and orientation, room layout, window design and shading. Insulation and thermal mass helps to maintain even temperatures, while ventilation provides passive cooling as well as improving indoor air quality. All of these elements work alongside each other and therefore should be considered holistically (Branz , 2015). For example, large windows that admit high levels of natural light might also result in excessive heat gain, especially if they cast light on an area of thermal mass. Similarly, opening windows that provide ventilation will also let in noise. Alongside passive design features, designers should also consider other factors such as views, covenants and local authority restrictions, and building owners' preferences (Branz , 2015).

2.1.3 Passive Design as Key to Sustainable Building

It responds to local climate and site conditions to maximize building users' comfort and health while minimizing energy use. It achieves this by using free, renewable sources of energy such as sun and wind to provide household heating, cooling, ventilation and lighting, thereby reducing or removing the need for mechanical heating or cooling. Using passive design can reduce temperature fluctuations, improve indoor air quality and make a home drier and more enjoyable to live in. It can also reduce energy use and environmental impacts such as greenhouse gas emissions. Interest in passive design has grown, particularly in the last decade or so, as part of a movement towards more comfortable and resource-efficient buildings (Branz , 2015).

2.1.4 Passive Design for Sustainable Building

Passive design features are elements that are permanently attached to or part of the building design such as building orientation, double skin envelope, sun-shading device, large overhang etc. The active design features are elements that bring in different results and actively react to the surrounding such as the solar panel, photovoltaic, rainwater harvesting, roof spray, landscape etc. Some of the features illustrated in a few literatures include those on the **passive cooling**, **lighting** and **ventilation** (Aziz & Adnan, 2010)**.**

Cooling of Buildings

Some of the passive techniques based on thermal protection of the building envelope and on the dissipation of buildings thermal load to a lower temperature heat sink, have been proved to be very effective (Aziz & Adnan, 2010). Passive technique as alternative to air conditioning can bring important energy, environment and financial, operational and qualitative benefits (Aziz & Adnan, 2010). A useful framework for considering passive and hybrid cooling in the context of environmental design can be summarized as follows: prevention of heat gain, modulation of heat gain and dissipation of heat. Protection from heat gain may include landscaping and the use of outdoor and semi outdoor spaces, building form, layout and external finishing, solar control and shading building surfaces, thermal insulation and control of internal heat gain (Aziz & Adnan, 2010). The designers of early skyscrapers tempered the heat from the sun by setting windows deep into the façade where they were sun shaded and helped shield the most exposed portion of the building. The application of the concepts within the framework may include the use of air movement through open spaces, external and internal shading, appropriate arrangement of immediate surrounding space vegetation, open pools and ponds and use of proper building materials

(Aziz & Adnan, 2010). Large opening of the building allow for ample cross air movement which can have a significant cooling effect. The use of vegetation for necessary shading will absorb large amount of incident solar radiation and maintaining lower air temperature which is further reduced by evaporation from the trees. Another approach is considering the building orientation in the design stage. Good site planning involves proper building shape and orientation by taking advantage of natural site features such as topography, sunlight, shade and wind to promote energy efficiency (Aziz & Adnan, 2010).

Ventilation

Natural or forced ventilation is paving way of reducing the cooling load in building. Natural ventilation is caused by pressure difference in the inlets and outlets of a building envelope, as a result of wind velocity and stack effects (Aziz & Adnan, 2010)**.**

Day lighting

Daylight is very important for people inside buildings physiologically and psychologically. The natural light can be capitalized by the use of windows, light shade, atria etc (Aziz & Adnan, 2010). The design should avoid direct sunlight penetration into the building instead sun light is diffused from strategically placed louvers that are painted eggshell white to achieve colourless, soft cool lighting (Aziz & Adnan, 2010). Glare is avoided by placing all such diffusing surfaces and glazing well above eye level. The colour, shape and material of the luminaries will affect distribution of light. Highly reflective wall coverings indirectly make the space feel brighter. What the interior need is ambient daylight without the radiant heat and glare which is called cool daylight / diffuse daylight. When daylight enters a room through windows, the illumination near the windows will be high and it reduces quickly as it gets further into the depth of the room (Aziz & Adnan, 2010). Designers should always

try to create a better uniformed daylight distribution into a space. The simplest and most often used strategy to improve the daylight penetration to the back of the room is by having high level windows or clerestory window, where the lower window is for vision and the higher level window is purely for daylight. A light shelf between the upper and lower window would help to distribute daylight deeper into the room by bouncing lights of the shelves to bring illumination deeper into the room (Aziz & Adnan, 2010).

2.2 The Concept of Sustainability

The concept of "Sustainability" started to be discussed in 1987 in United Nations with the report by the World Commission on Environment and Development, which defined sustainable development as "meeting the needs of the present without compromising the ability of future generation to meet their own". Since then the term 'sustainability' and such expression as 'green', 'eco' and 'environmentally friendly' have been used to describe multitude of products and actions that show concern for the earth's resources. The overuse of these terms has threatened to reduce the potency of their meaning. Principles that can summarize sustainable design are; to build small, make spaces efficient, use recycled or recyclable materials, recycle and compost all waste, build recycling centres in facilities, use renewable resources, create safe healthy living environments, easy operated, durable and easily maintained (Reinhart, Mardaljevie, & Rogers, 2006).

On the other hand "Sustainability" in any area requires a harmonious relation of social, environmental and economic factors. Considering the results of researches, regarding the vast amount of energy consumed by buildings only 5% is spent by the construction processes while more than 45% is spent by management, repair and maintenance activities. These output data suggest that building industry is going to play a major role in the

continuing efforts to decrease the total energy consumption or at least shift some of this consumption from non-renewable resources to renewable ones. In this point of view, the concept of Sustainable Design and Sustainable Architecture should be clearly defined (Wong, 2001). Sustainable design stands for a holistic creative process, which "seeks to translate and embody global and regional socio-environmental concerns into products and services at a local level. This necessarily demands a system view of design" (Reinhart, Mardaljevie, & Rogers, 2006). Sustainable architecture is an approach to architectural design that emphasizes the place of buildings within both local ecosystems and the global environment. Sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development space (Reinhart, Mardaljevie, & Rogers, 2006).

Design can play a key role in the creation of a sustainable future. Design can integrate ecological requirements in the business creation process and go far beyond it. Acting as a bridge between people, technology and business, design can facilitate the systematic integration of economic, social and environmental parameters in the framework of new and more sustainable patterns of production, marketing, distribution and use. Design can become a powerful engine for suitable innovation. It can help businesses in generating solutions able to stimulate new social behaviours (e.g. accessibility versus ownership, sharing versus individual use, upgrade ability versus substitution) whilst still supporting economic societal needs. In this way, it complies with the change in the complex world that is required from design culture; from eco-design to sustainable design (Moussatche & Languel, 2002). Moving from the important role of design in the concept of sustainability,

we can clearly identify that; passive design requirements can play an important role for sustainable shopping Malls as well.

2.2.1 General Principles of Sustainable Design

The Concept of integrative and sustainable design recognizes that human civilization is an integral part of the natural world and that nature must be preserved and perpetuated if the human community itself is to survive.

Sustainable Design articulates this idea through approaches that exemplify the principles of conservation and encourage the application of those principles in our daily lives.

“Sustainable design”, “green design”, “design With nature”, “environmentally Sensitive design”, “ecologically Sound design” Regardless of what it's called the capability of natural and cultural systems to coexist over time, is key. Sustainable Design embraces environmental stewardship, social responsibility, and long term economic viability. Sustainable Design recognizes the impacts of every design choice on the natural and cultural resources of future generations (McDonough & Braungart, 2000).

Sustainable design should be achieved at three levels; ecological, economic, social and cultural levels. These three levels of sustainability are interwoven in order to maximize human well-being and comfort as seen in Figure 2.1.

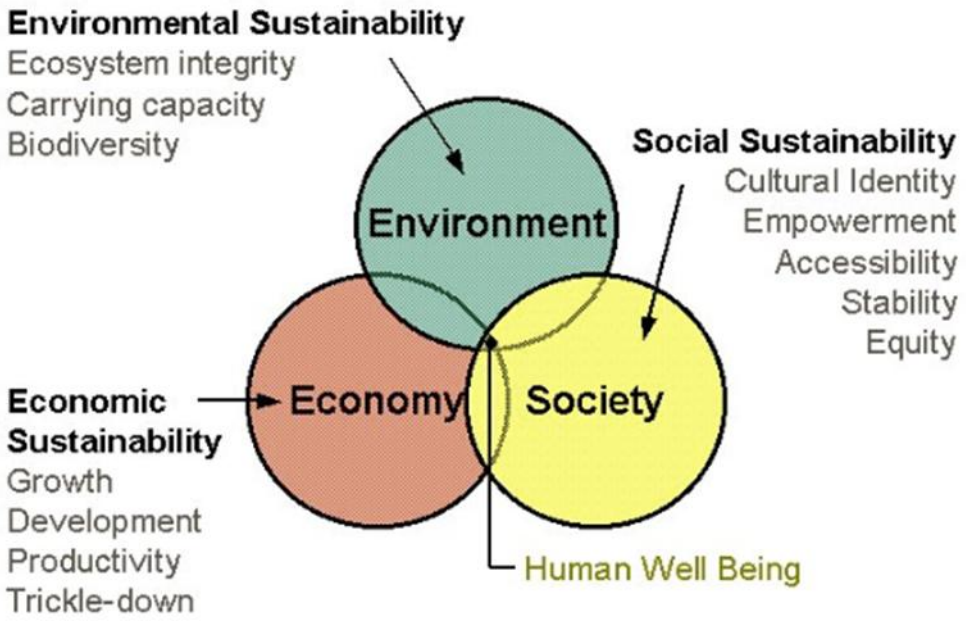


Figure 2.1: **The three levels of sustainability**
Source: Samuel (2011)

2.2.2 Sustainable Architecture.

Sustainable architecture is a term that describes environmentally conscious design techniques in the field of architecture. In the broader context, sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space. The idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations. The term can be used to describe an energy and ecologically conscious approach to the design of the built environment (Sirija, 2013).

2.3 Passive Cooling.

Before energy was plentiful and air-conditioning omnipresent, designers came up with ingenious techniques for letting the forces of nature keep their buildings cool. Today's designers are relearning those techniques, coming up with a few more As much as possible. Controlling the heat building gains from its environment is what passive cooling is all

about. It is also what passive heating is about, and the relation between those two functions is crucial. Keeping unwanted heat out in the summer and drawing it in during winter are issues that should in fact, must be addressed hand in hand, for the simple reason that in either case the design of the building itself is the climate-control mechanism. There are designers, who define passive cooling techniques as strategies which literally introduce coolness into a building without mechanical assistance, a definition that excludes design strategies which stop heat before it can enter and become part of the cooling load. While it's a definition that has real meaning, especially in its opposition to active mechanical cooling strategies, even its proponents agree that controlling heat gain is the essential first step in any attempt to cool buildings naturally, passively, through designs itself (Passive cooling loads, 2012).

2.3.1 Passive Cooling Strategies

Passive cooling strategies prevent the building from overheating by blocking solar gains and removing internal heat gains (e.g. using cooler outdoor air for ventilation, storing excess heat in thermal mass) (Marler, 2009). Passive cooling strategies are often coupled with passive ventilation strategies, and the cooling function is achieved by increased passive ventilation air flow rates during periods when the outdoor air temperature is low enough to flush heat from the building (Marler, 2009). Elements that contribute to passive cooling include the following:

1. Fixed/operable external shading
2. Thermal mass
3. Low window to wall area ratio (S/W)

4. Passive ventilation
5. Natural cooling
6. Stacked windows
7. Passive evaporative cooling
8. Earth-tempering ducts (Marler, 2009)

2.3.2 Passive Ventilation

Designing a building in a way that maximizes natural ventilation will greatly reduce the need for energy-intensive air conditioning. Air movement over the body, even if the air is not much cooler, creates a feeling of cool due to the evaporation of moisture from the skin. The following are methods of passive ventilation (Marler, 2009).

Maximizing breezes

- Orient the building to make the most of prevailing winds.
- Align vents, windows and doors to allow air flow through the building – these should be aligned in a reasonably straight line for maximum effectiveness.
- Minimise internal obstacles or blockages such as internal walls in major flow through areas to allow for unimpeded ventilation.
- Raise the building off the ground to catch breezes (Marler, 2009).

Removing Hot Air

- Design for convection air flow to remove hot air from the building. Convection air flow is created by hot air rising and exiting at the highest point, which naturally

draws in cool air from outside. This natural cycling of air can be created by placing low window openings across a space from high window openings. This will be even more effective at cooling if incoming air is being drawn from a shaded area where plants are growing. As shown in Figure 2.2, 2.3 and 2.4 below.

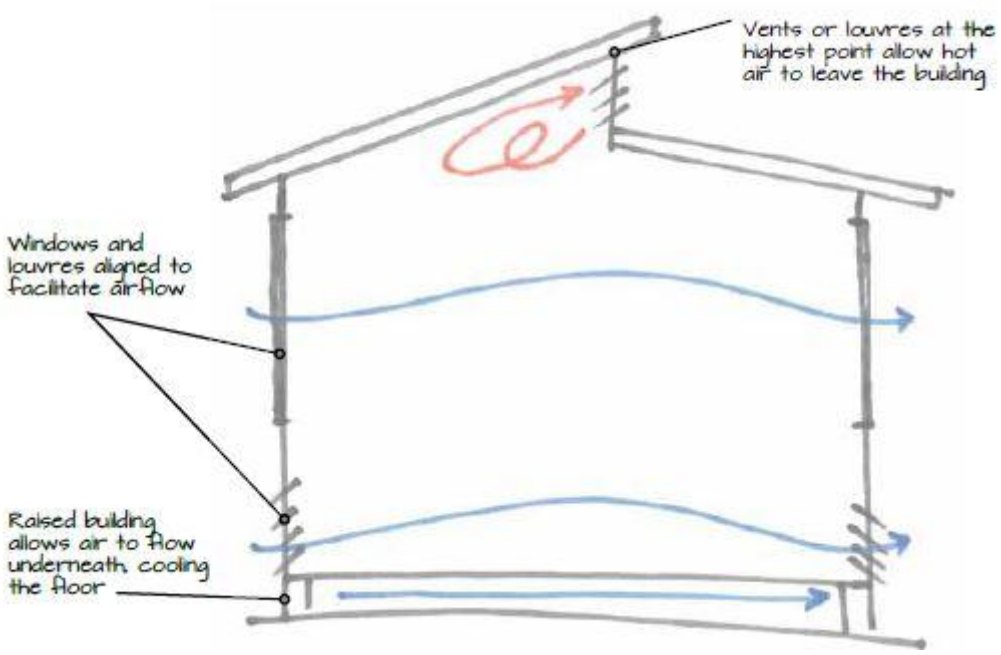


Figure 2.2: **Passive ventilation (Cross Section)**

Source: (Cairns Regional Council, 2011)

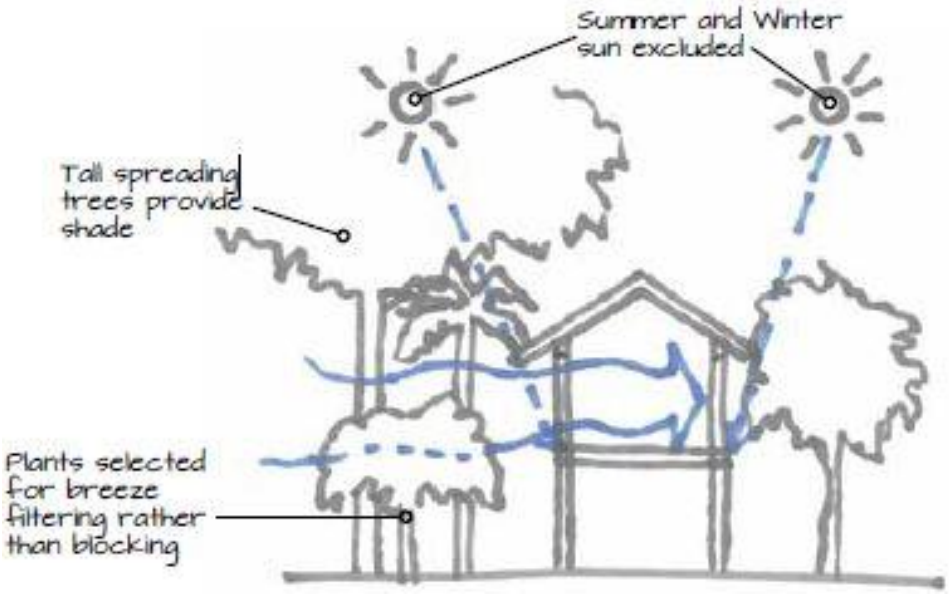


Figure 2.3: **Shading and Landscaping**

Source: Cairns Regional Council (2011)

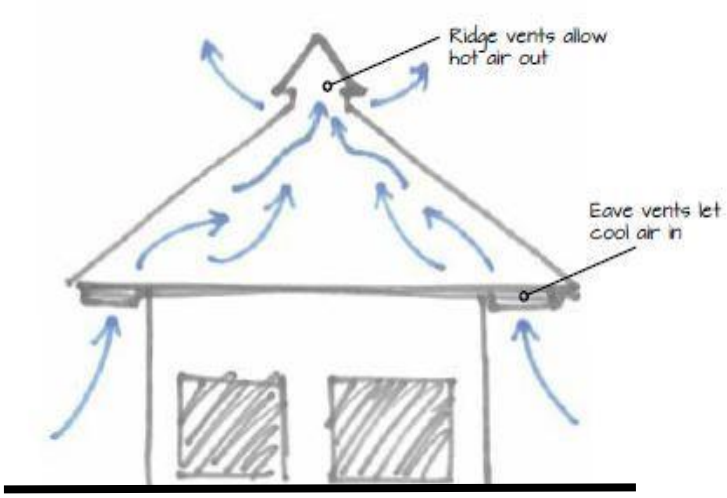


Figure 2.4: **Roof Cavity Ventilation**

Source: (Cairns Reginal Council, 2011)

2.3.3 Dehumidification

In regions of high humidity, where moisture in the air actually prevents the body from cooling itself evaporatively, desiccant cooling is a valued traditional strategy (Passive cooling loads, 2012). Dehumidifiers have replaced the salt barrels that were once ubiquitous in the Southeast, but before energy was harnessed and plentiful, desiccant salts were effective coolers to which the only drawback was the need to throw them out once they were saturated. Passive cooling in regions of high humidity remains a problem today, and desiccant solutions remain the focus of research and current design experimentation (Passive cooling loads, 2012). One new hybrid system in use rotates two desiccant salt plates, one of which is inside the living space absorbing moisture from the air while the other, already saturated, is outside in the sunlight losing its moisture through evaporation and being readied for reuse (Passive cooling loads, 2012). Another system combines induced ventilation to bring air from underground over an activated charcoal desiccant and cool the interior with dry air. As the air warms and exits high on the south wall, it passes over the saturated desiccant plate, spurring the evaporative process (Passive cooling loads, 2012). The selection of activated charcoal over desiccant salts in the latter system is the product of research, which is rampant in this particular area; one chemical researcher reports that coconut husk charcoal may be the most effective natural desiccant available. The real frontier in desiccant research, however, as in other areas of passive design, is to develop a system capable of cooling buildings larger than residential scale (Passive cooling loads, 2012).

2.3.4 Passive Ventilation Strategies

Passive ventilation strategies use naturally occurring air flow patterns around and in a building to introduce outdoor air into the space. Wind and buoyancy caused by air temperature differences create air pressure differences throughout occupied spaces. Buildings can be designed to enhance these natural air flows and take advantage of them rather than work against them. Passive ventilation must be considered during the design process because many architectural features affect air flows through a building, including the building shape, layout of interior walls, floors and even furniture. There are three common approaches to passive ventilation.

The simplest form is **single-sided ventilation** with operable windows, where ventilation air enters and exhausts through the same window(s) on the same side of the occupied space. There are design limitations on how large a space can be effectively ventilated this way: single-sided ventilation does not achieve a significant result unless ceilings are very high (Marler, 2009). As shown in figure 2.5 below.

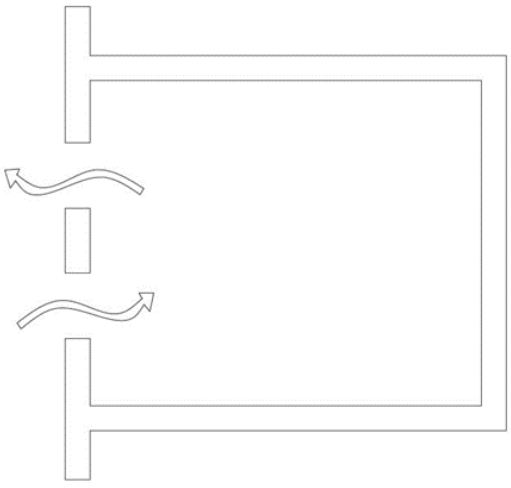


Figure 2.5: **Single Sided Ventilation**

Source: Marler (2009)

More effective is **cross-ventilation**, where operable windows on adjacent or opposing walls draw ventilation air across the occupied space. Designs should strive for at least two exposed walls per residential or commercial unit to allow for cross-ventilation. As shown in figure 2.6 below.

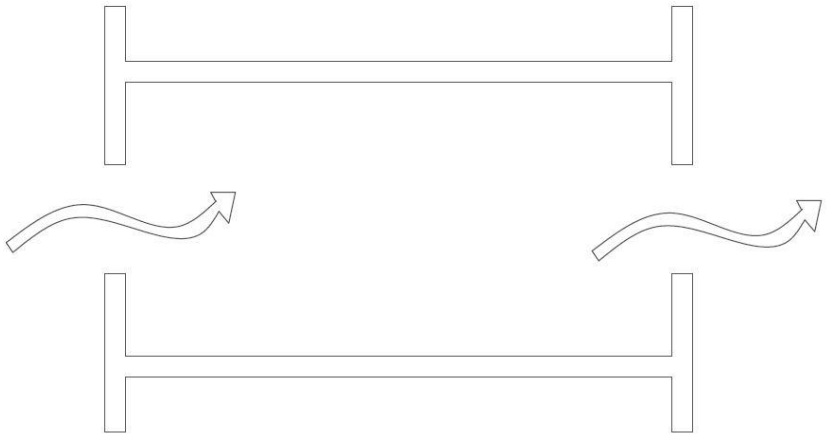


Figure 2.6: **Schematic Representation of Cross-Ventilation**

Source: Marler (2009)

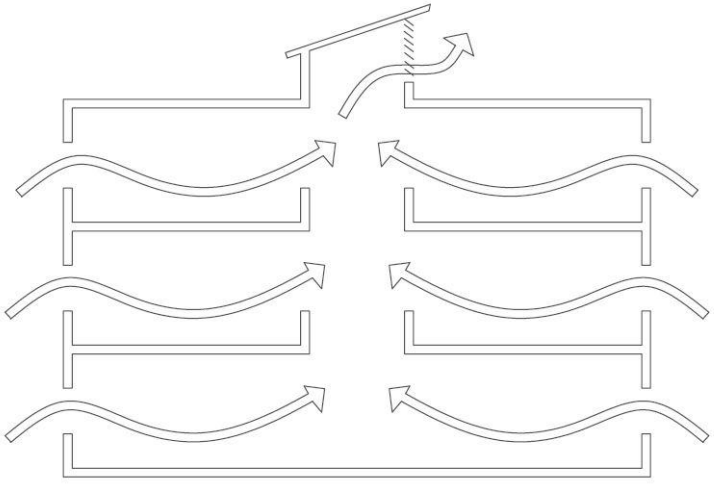


Figure 2.7: **Atrium (stack effect)**

Source: Marler (2009)

Finally, in larger buildings with significant core spaces, induced ventilation with high spaces such as atria, stacks and wind towers may be necessary to provide adequate ventilation by strictly passive means. These strategic architectural features create optimized pathways for natural, passive ventilation. As shown in figure 2.7 above.

The passive elements that contribute to natural ventilation include the following:

- Operable windows
- Buffer spaces and double facades
- Building shape
- Space planning
- Orientation
- Strategic architectural features
- Openings to corridors and between otherwise separated spaces
- Central atria and lobbies
- Wind towers (Marler, 2009)

2.4 General Principle of Passive Cooling

Passive cooling is the counterpart of passive heating. While passive heating is driven only by the sun, passive cooling can use various heat sinks and climate influences to decrease heat, (Passive cooling loads, 2012) these include:

- Natural ventilation

- Evaporative Cooling
- Dehumidification
- Radiative Cooling
- Time lag cooling
- Earth cooling

2.4.1 Natural Ventilation

The cooling value of air movement lies in its capacity to evaporate perspiration from the body and allow one to feel cool. Nowhere is that effect more celebrated than in the antebellum architecture of the Southeast in Charleston, S.C., the breezes sweeping in from the ocean bring otherwise intolerable conditions down into the comfort zone (Passive cooling loads, 2012). Those breezes are so powerful they have generated an indigenous architectural style: the single-house design peculiar to Charleston and direct their faces to the harbour, not the street, and draws its ocean air through a tree-shaded piazza and a broad veranda before channelling it through every room in a floor plan carefully designed for cooling. Like so much of the hot, humid Southeast, Charleston was designed with natural ventilation in mind (Passive cooling loads, 2012). In dry climates, however climates averaging lower than 20 per cent relative humidity the same process can dehydrate the body and, if not eased by evaporative cooling, cause radical discomfort. Where ventilation is a wise cooling technique, and where summer winds regularly occurring at five miles per hour or greater make it effective, buildings should be sited for summer wind exposure, opened with louvered, vented, and windowed walls, and planned for through-ventilation (Passive cooling loads, 2012).

2.4.2 Evaporative Cooling

Swamp coolers, fountain courts, and atrium pools are all applications of evaporative cooling, a particularly powerful technique in climates of low relative humidity (Passive cooling loads, 2012). When a body of water is placed in a hot and relatively dry space, the water evaporates into the air and increases humidity. In the process it turns sensible heat into latent heat, literally lowering the temperature of the air at a rate equivalent to 1,000 BTUs lost for every pound of water added to the air (Passive cooling loads, 2012). Evaporative cooling can also be put to work to cool a radiative roof deck or any other radiative surface in contact with interior spaces. If a roof is sprayed with water, evaporation cools the roof surface, encouraging its absorption of heat from the interior and the dispersal of that heat into the atmosphere (Passive cooling loads, 2012). Effective as it can be, an evaporative cooling strategy mandates certain considerations: Water must be available in quantity to supply an evaporative system, and since such systems are most effective in dry climates, water supply can be a problem. It is a strategy that requires shade as well, since it is the air's heat, not solar heat, that the process is capable of modifying. And a cooling strategy employing evaporation should be joined with ventilation for the most efficient distribution of cool, humidified air (Passive cooling loads, 2012).

2.4.3 Radiative Cooling

Radiative cooling is an indirect heat-loss process that involves exposing interior spaces to the heat sink of a massive body of water or masonry, then exposing the mass to the planetary heat sink of a cool, clear night sky (Passive cooling loads, 2012). The mass absorbs heat from the interior, and then releases that heat—in the same process that maintains Planet Earth's thermal equilibrium—to the skydome. The only caveat in the

process is that it is most effective where the diurnal (day-night) temperature swing is in excess of 20°F and where the night sky is relatively clear (radiative losses to the vast heat sink of deep space are impeded by the greenhouse effect of cloud cover) (Passive cooling loads, 2012). Masonry massing is the key to such historic examples of radiative design as the puebloes and Spanish missions of the Southwest, but since the invention of Harold Hay's patented Skytherm system attention has been focused on using roof-sited water as the radiative mass (Passive cooling loads, 2012). In a typical roof-pond (or thermo-pond) building, bags or bins of water on the roof are covered with moveable insulation during the day to absorb heat from the interior spaces below. At night the insulation is removed and the heat stored in the water is released to the cool sky dome. Other systems designed along the same lines use floating insulation which can be immersed in the roof pond at night, or stationary insulation over which the water is piped at night (Passive cooling loads, 2012). In any configuration, radiative cooling is popular in both the research and design communities because it doubles for heating in winter; the exposed mass absorbs solar radiation by day and, insulated from the sky, transmits heat to the interior spaces by night. The strategy's efficacy as a cooling technique can be improved by sprinkling waters on the rooftop water containers to add evaporative cooling to the radiative effect (Passive cooling loads, 2012).

2.4.4 Time Lag Cooling

Like radiative cooling, time lag cooling takes advantage of the thermal absorption, reduction, and lag characteristics of mass, and requires the same 20-35°F diurnal temperature swing to be effective (Passive cooling loads, 2012). Where the conditions are right, time lag cooling has been around for centuries. The principle is that the transmission

of heat through mass—stone, concrete, adobe-—is both delayed and attenuated over time. Depending on the material and the thickness of a massive wall, the delay can stretch from two to 12 hours, and the greater the lag the greater the attenuation of heat transmitted. Thus less heat reaches the interior spaces, and it doesn't arrive until late evening or night, when ambient temperatures have dropped and the exterior wall is radiative cooling. By night's end the wall is again a cold barrier to the daytime onslaught of insulation. Exterior sheathing, insulation, or shady vegetation will add to that barrier (Passive cooling loads, 2012).

2.3.5 Earth cooling

Warm in dry season, cool in wet season, the earth is where mankind first sought shelter, and for good reason (Passive cooling loads, 2012). Below the frost line, ground temperatures remain remarkably stable, hovering around the average annual air temperature, usually in the range of 50-65°F. At shallow depths, ground temperatures actually fluctuate with the seasons, but the much smaller fluctuations come as far as three months behind schedule. Thus the earth not only attenuates extreme air temperatures, but acts as a maximal time lag device, carrying winter coolness well into late spring and summer warmth into late fall (Passive cooling loads, 2012). Underground or earth-integrated construction, the common way of exploiting the moderating influence of the earth, takes advantage of both these virtues, and putting part or all of a building below grade reaps substantial cooling (and heating) benefits. There are, however, problems, not the least of which is the cost of excavation. Soil erosion, soil instability, and ground water are also crucial considerations (Passive cooling loads, 2012). Another method for taking advantage of Mother Earth is to pre-condition air by running it through subterranean cool

pipes before it enters the building, or by storing it in a below-grade rock storage chamber before use. The hazards of such methodology cost, condensation, and ground water in particular—are no less real than in earth integrated construction (Passive cooling loads, 2012). But the field is undergoing considerable research and experimentation aimed at defining and overcoming these particular difficulties, and at quantifying the feasibility of numerous earth-cooling design strategies, including the tapping of cool underground water supplies for radiative and evaporative cooling applications (Passive cooling loads, 2012).

2.5 The Microclimate

If the best offense is a good defence, the best passive cooling strategy pays as much attention to the microclimate surrounding a building as to the building itself. Landscaping and vegetation can have a tremendous impact on natural comfort inside a building, affecting both hot cooling and winter heating loads, both of which should be considered in the physical design of a site (Passive cooling loads, 2012). Massed earth is particularly effective as a windbreak. Earth berming can be used to deflect winter winds, to channel summer breezes into interior spaces, and to shape the air circulation pattern around a building (Passive cooling loads, 2012). Vegetation is an asset of greater worth. Evergreens make excellent windbreaks, and deciduous plants, shedding their leaves to allow the penetration of solar radiation in winter, in summer become complex cooling mechanisms (Passive cooling loads, 2012). Deciduous leaves reflect infrared, heat-bearing energy and filter cool, green light to the ground. Combined with air movement, the evaporation of water into the air that occurs in plant transpiration has an evaporative cooling influence. The general effect in an area of massed vegetation is to keep temperatures in the shade a

good 10-15°F lower than ambient a particularly valuable phenomenon if that cooler air can be sent into the building (Passive cooling loads, 2012).

2.6 Energy Efficiency in Buildings

More than 40% CO2 emissions in developed countries come from heating, cooling and powering buildings. It was estimated that cutting UK building emissions by 25% would have a similar impact to take every car off the road in the UK (Zhang & Philip, 2010). For existing buildings, good insulation, efficient boiler, window glazing and recovering heat from ventilation systems are efficient ways to reduce emissions. For existing buildings in the tropics things like efficient boiler and recovering heat from ventilation systems are not necessary because avoid heat gain is a critical principles of passive design for buildings in the tropics. The benefits of energy efficiency in building are summarized as following:

- Energy efficiency in buildings is compelling, cost effective and can help consumers to save money in the long term.
- Energy efficiency in buildings helps to meet energy targets and resource energy shortage.
- Energy efficiency is good for industry and creates new jobs for
- Saves the environment (Zhang & Philip, 2010).

2.6.1 "Zero-Energy" Or "Zero-Carbon" New Buildings

Zero-energy" building, "net zero energy" building or "Zero-carbon" building is a general term applied to a building's use with zero net energy consumption and zero carbon emissions annually, much building energy is wasted because of poor design, inadequate technology and inappropriate practices (Zhang & Philip, 2010). The concept of "Zero-

energy" building has been introduced recently to focus on energy consumption. The carbon emissions generated from on-site or off-site fossil fuel uses are balanced by the amount of on-site renewable energy production, so it is also called as "zero-carbon" building. "Zero-energy" buildings are usually built with significant energy-saving features such as building orientation, solar panel roofs and super insulated HAVC system (Zhang & Philip, 2010). The goal of green building is to increase the efficiency of resource use (including energy, water and materials) and reduce the building's negative impacts on the environment during the building's lifecycle. "Zero energy" buildings achieve one key green building goal of reducing energy use and greenhouse gas emissions. They may or may not be considered "green" in all areas such as reducing waste etc., but they reduce ecological impact. Meanwhile, many green building certification programs worldwide do not require a building to have net zero energy use, only require a building to reduce energy use below the standard limit by law (Zhang & Philip, 2010).

2.6.2 "*Passivhaus*" or "Passive House" in EU

"Passive house" (*Passivhaus* in German) refers to energy efficiency buildings mainly built in Europe. It requires little energy for space heating or cooling. Passive houses can be warmed not only by the sun, but also by the heat from appliances and even from occupants' bodies. Up to date, about 15,000 to 20,000 passive houses have been built worldwide, most of them in German-speaking countries or Scandinavia, including residential homes and offices, new and renovated buildings. For buildings in the tropics passive house buildings are called eco-friendly buildings. According to a report by the World Business Council for Sustainable Development (WBCSD, 2008), there are five key elements for passive houses:

- The envelope - all components should be highly insulated

- Air-tightness - stop air leakage through unsealed joints
- Ventilation - use a mechanical system with heat recovery
- Thermal bridges - control heat loss from poorly insulated points such as window and doors
- Windows-minimize heat loss in winter and heat gain in summer.

2.7 Shopping Mall

A shopping centre is a group of retail and other commercial establishments that is planned, developed, owned and managed as a single property, typically with on-site parking provided. The centre's size and orientation are generally determined by the market characteristics of the trade area served by the centre of International Council of Shopping Centres (ICSC, 2004).

A **shopping mall** is a modern, chiefly North American, term for a form of **shopping precinct** or **shopping centre**, in which one or more buildings form a complex of shops representing merchandisers with interconnecting walkways that enable customers to walk from unit to unit (ICSC, 2004). A **shopping arcade** is a specific form serving the same purpose. Many early shopping arcades such the Burlington Arcade in London, the Galleria Vittorio Emanuele II in Milan and numerous arcades in Paris are famous and still trading. However, many smaller arcades have been demolished, replaced with large centres or "malls", often accessible by vehicle. Technical innovations such as electric lighting and escalators were introduced from the late nineteenth century. From the late twentieth century, entertainment venues such as movie theatres and restaurants began to be added. As a single built structure, early shopping centres were often architecturally significant

constructions, enabling wealthier patrons to buy goods in spaces protected from the weather (ICSC, 2004)

Shopping Mall - mercantile establishment consisting of a carefully landscaped complex of shops representing leading merchandisers; usually includes restaurants and a convenient parking area; a modern version of the traditional marketplace; "a good plaza should have a movie house"; "they spent their weekends at the local malls". Free dictionary by farlex.

Karmer (2008) Considers that well-planned shopping centres are defined most clearly by their characteristics, thus, they are described by the following eight characteristics:

- Coordinated architectural ensemble, which can consist of differently shaped and different type of buildings, but which are planned in concordance
- A uniform area, which results in a centre that befits the market requirements in terms of type, size and functionality
- A site that is within easy reach of the local residents, travellers in transit, pedestrians and those who use different means of transport
- Ensures a sufficient number of parking spots
- Various services available to customers (e.g. home delivery)
- Creates an attractive and secure shopping environment - offers adequate tenant and retail mix to the commercial area and creates synergy by the assortment of different stores
- provides a convenient and comfortable space both for shopping and other related activities, creating by this a strong sense of identity and place consciousness

Although this list exhausts the main characteristics of shopping centres, it still cannot be considered complete, especially since through the years many different shopping centre types were created and several various classifications were elaborated Karmer (2008).

2.7.1 Historical Overview of Shopping Mall Development

There are several different viewpoints regarding the first emergence of shopping centres. For instance, the Al-Hamidiyah Souq in Damascus or the Grand Bazaar of Istanbul as shown on Plate I; is seen as the medieval predecessors of shopping centres (Reikli, 2012). The Gostiny Dvor built in 1785 at Saint Petersburg housing 100 stores on 53.000 square meters can be seen as the first planned shopping centre predecessor (Reikli, 2012). Following this, the Burlington Arcade was built in London, while the Árcade was built in Rhode Island, in the United States of America (Reikli, 2012). In Europe, many see the Galleria Vittorio Emanuelle II, built in 1870 in Milan, as the first shopping centre. In parallel with the appearance of automobiles, the first shopping centres at the outskirts of cities were built in the United States of America, for instance, Market Square, in the city of Lake Forest, Illinois, in 1916, or the Country Club Plaza in Kansas City, Missouri, in 1922 (Reikli, 2012). The first open-air suburb shopping centre named Northgate Mall opened its doors to visitors in 1950, in Seattle, Washington, housing 80 stores and one anchor tenant. In spite of all these, the most generally acknowledged and cited milestone of shopping centre development is the Southdale Centre, which opened in 1956, in Twin Cities, Minnesota. This is the first, completely closed, regional-sized shopping centre, which was built according to the plans of the Austrian-born Victor Gruen (Reikli, 2012). This mall type of shopping centre proved to be so successful in the United States that other enclosed malls followed in line: Harundale Mall – Maryland, Big Town Mall – Texas, Chris-Town

Mall – Arizona, Randhurst Centre – Illinois. In the following decades, more and more shopping centres opened in the United States, and by 1992 the U.S. Census Bureau counted already 38.000 shopping centres, with a sales area of 4,586 billion square feet and a turnover of 717 billion dollars (Reikli, 2012).



Plate I**: Grand Bazaar, Istanbul.**

Source: Reikli (2012)

2.7.2 Typology of shopping centres

According to the industry's practice the accepted classification defined by the International Council of Shopping Centres (ICSC , 2004) is used most frequently. According to this, and to their architecture and design, shopping centres are classified into three groups. Within this, nine shopping centre types are defined:

1. **Mall or Shopping Mall** - closed shopping centre, with shopping streets and alleys that have controlled air-conditioning and lights.

a. **Regional Centre** - it has a general retail range; fashion apparel and services are present in a bigger proportion. Its main attractiveness lies in the combination of anchor tenants and in the mix of fashion apparel stores as shown on Plate II below.



Plate II: **Westend city centre, Budapest.**
Source: (ICSC, 2004)

b. Superregional Centre - very similar to the regional centre, just bigger. Thus, it has more anchor tenants and the store range is wider, and it's often a multi-storey building as shown on Plate III below.



Plate III: Alstertal, Hamburg
Source: (ICSC, 2004)

2. **Open-air Centre** - in which the store-strips follow each other; they have common parking lots located in front of the stores, but do not have closed streets. Their most common formats are: L-, U- and Z-shaped, while the simple I-shape is used in residential areas and community centres. These were formerly known as strip centres, but this name was used mainly because of the I-shaped linear centre.
   a. **Neighbourhood Centre** - shopping centres which facilitate convenience shopping of products that satisfy everyday needs and which are developed in residential areas. In more than half of these facilities the anchor tenant is a supermarket and in most of the cases they are I-shaped as shown on Plate IV below.



Plate IV: Stop. Shop, Budapest.
Source: (ICSC, 2004)

b. Community Centre - these have a wider range of products, especially when it comes to fashion apparel. Their typical anchor tenants are the same as those of the neighbourhood centres, but here and there a dominant big-box retailer can be found, with products such as clothing, home improvement, and toys, electronics or sports equipment. Shape-wise, they can have an I-, L- or U-format. These are the most diversified among the shopping centre types as shown on Plate V below.



Plate V: Family centre Gyr.
Source: (ICSC, 2004)

c. **Power Centres** - they are characterized by many anchor tenants, from which the discount stores, warehouse stores or category-killer retailers should be underlined. Building-wise, these can be separate big boxes with few small-sized specialized stores as shown on Plate VI below.



Plate VI: **Market central Ferihegy, Vecses.**

Source: (ICSC , 2004)

d. Theme/ Festival Centre- these are developed on a common theme both in terms of architecture and product, retail offerings. Entertainment is an important element for these centres, that is why they usually attract tourists, but local residents also visit them as shown on Plate VII below.



Plate VII: Kanyon, Istanbul
Source: (ICSC, 2004)

e. Outlet Centre- these house mostly manufacturers' and retailers' outlet stores, thus, they provide good quality and well branded products at discount prices. They usually do not have an anchor tenant, but some brand stores have a strong attractive power. Shape-wise, they are usually open-air strips or village-like, but they can also be closed as shown on Plate VIII below.



Plate VIII: **Pamdorf, Austria.**
Source: (ICSC, 2004)

f. Lifestyle Centre -in most of the cases they are built around high-earning residential areas, and they try to combine the shopping and lifestyle needs of the catchment areas' residents. They house higher-priced specialized stores, and in the spirit of multi-purpose recreation they provide restaurants, entertainment and pleasant, city centre-like environment (fountain, benches, park etc.) for visitors. Their anchor tenants are usually fashion-oriented specialized stores as shown on Plate IX below.



Plate IX: **Istinye park, Istanbul**
Source: (ICSC, 2004)

3. **Hybrid Centres**- these centres are created practically by the combination of the latter two groups, take for instance the case of value-oriented mega-malls, where the same establishment houses a mall, a power centre and even an outlet as shown on Plate X below.



Plate X: **Istinye park, Istanbul- hybrid centre**
Source: (ICSC, 2004)

2.7.3 Sustainable Approaches in Contemporary Shopping Malls

Shopping malls are fast becoming one of the most dominating structures in Nigeria cities, considering the number, the body structure and the area of shopping malls, the importance of passive design approaches in shopping malls design have become more important aspect to be studied in Nigeria. Although it is a known fact that science and technology have a crucial role in shaping sustainable human settlements and sustaining the ecosystems they depend upon. Architects, planners and engineers a have a great responsibility to help creating the receptiveness for the emergence of a new kind of architecture, a new language of construction technology, which is called sustainable architecture. As Norman Foster mentioned, sustainability is the achievement of the “maximum” by using the minimum rate of resources. But sustainability should first of all comprise the equality; sharing and it

should also construct the balance between the natural environment and the artificial configurations (Brown, 2005). Regarding this, sustainable architecture should consider the construction as a piece of world ecology and should combine climatic responsiveness with functional efficiency and a pleasing appearance. A sustainable buildings' design should include considerations regarding orientation, natural ventilation, daylight, solar control and thermal capacity, which could result in potent form-finding building elements. Taken together, they can trigger a new architecture language, which is the discourse of the energy conservation requirements by composing the equilibrium between the world economy and its ecological systems. In this context, architecture and the environment are inextricably linked and their relationship becomes complex and multi-faceted by considering the principles of sustainable development (Ferreira & Mendes, 2004).

Contemporary shopping malls should also follow those design criteria as well:

- Avoid restricting natural conditions reaching their internal spaces that would be of positive benefit to their occupants. For example, buildings should be designed to maximize the use of daylight over artificial light; likewise buildings should aim to be naturally ventilated with fresh air rather than be controlled through energy consuming heating and ventilation systems.
- Assist in the collection and storage of received energy sources, particularly solar energy, and then utilize this when and where required. Buildings should also be designed so that they consume far less energy.
- Should respect their local surroundings environmentally. Not only should they minimize internal energy consumption; they should also aim not to create external

demands or induce negative environmental effects. Local energy cycles can be utilized, but should not be altered or used in an unsustainable way (Gissen, 2003).

2.7.4 Day Light in Shopping Centres

Researches identify that, 35% of the energy used in buildings are utilized for lighting. Energy consumption in Shopping centre buildings, which have huge volumes and great number of users can be decreased by using day lighting. Considering the volume, function and user amount of the public spaces of shopping centres are the most suitable areas for the use of daylight (Moussatche & Languel, 2002). Daylight is generally associated with high window-head heights, high reflective ceiling and wall finishes, narrow floor plans, large facade and skylight openings with high transmittance glazing (Moussatche & Languel, 2002).

2.8 Shopping mall components

2.8.1 Anchor tenant

Components of the Mall are anchor stores which are departmental stores, normally owned by popular corporate bodies, meant to serve as a main pull factor to the mall. They are also known as draw-tenant. Anchors generally have their rents heavily discounted and may even receive cash inducements from the mall to remain open (Darlow, 2000). In physical configuration, anchor stores are normally located as far from each other as possible to maximize the amount of traffic from one anchor to another.

2.8.2 Hypermarket

The hypermarket is a European derivative. In the United States, it is equivalent to the supercenter or superstore. A hypermarket is similar to a community center in terms of the

types and range of goods offered but is more similar to a regional center in terms of establishing a quasi-monopoly position. Essentially a hypermarket is a horizontally integrated community center where the typical retailers of a community center including the grocery, drug, apparel and general merchandise stores are operated by a single owner under one roof with a centralized checkout for all types of goods (Vemor, Amundson, Johnson, & Rabianski, 2010)

2.8.3 Entertainment centers

Entertainment center have various mixes of dining, entertainment and unique experiences to drive frequent shopper visits. This attraction may include cinemas, children's play areas, amusement parks, and other non-traditional shops (Vemor, Amundson, Johnson, & Rabianski, 2010).

2.8.4 Food court

A shopping mall's food court consists of shops and stalls offering different cuisines. These shops may be owned by an individual or by several companies making the food court a franchised food court (Neufert, 2000). In a typical food court, meals are ordered at one of the shops then carried to a common dining area, which is normally a plaza contiguous with the counters of the multiple food vendors.

2.8.5 Retail shops

They are inward-looking and hence open into aisles meant for pedestrian traffic flow. They usually serve a sparsely populated region and stocked with a wide variety of goods. The selling of goods to consumers are usually in small quantities, hence these shops are small in

size with minimum floor space of 6.25m^2. They normally have the front doors open for air circulation and showcase of products (Neufert, 2000; Green, 1991).

Figures 2.8 below illustrate the systematic breakdown of the shopping components into its various functional space requirement; this approach when applied enhances effective passive design.

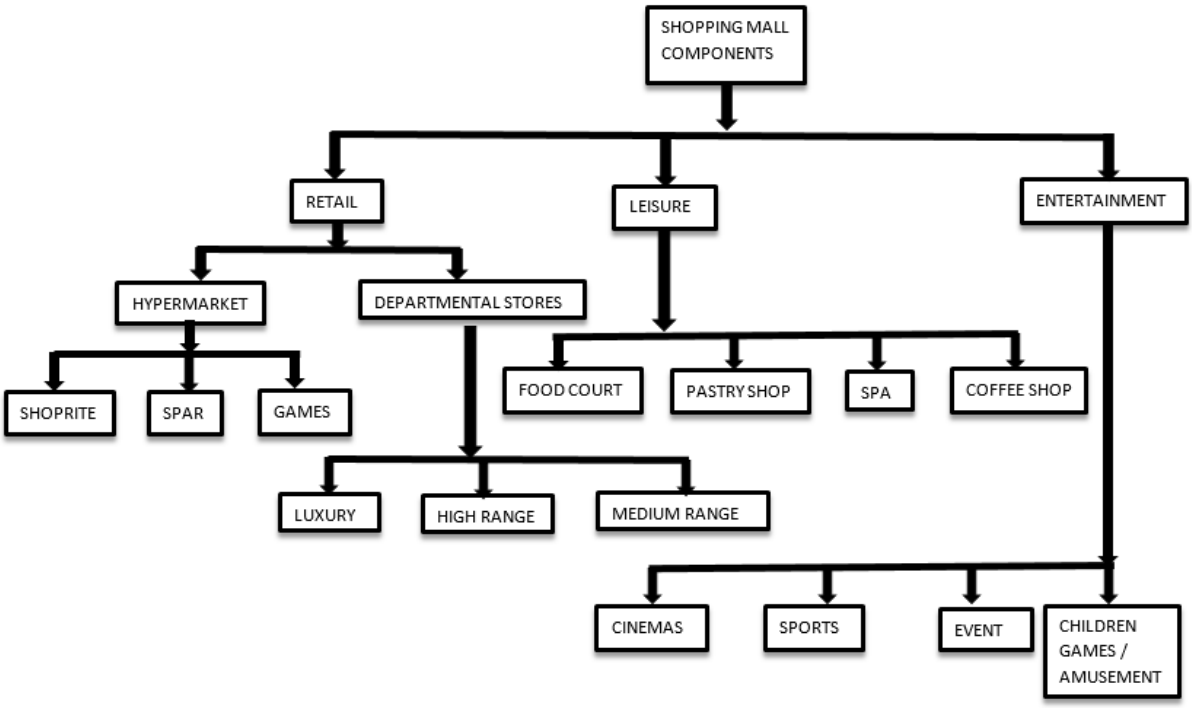


Figure 2.8: **shopping mall components**

Source: Author (2017)

2.9 Theoretical Framework for Sustainable Passive Design in Buildings

It is evident from the above literature review that passive design in buildings is vital for many reasons. Having justified the needs for passive design it is now important to focus on the basic principles that can bring about passive design in shopping malls design. An extensive literature review consisting of different journals, books, researches and related

websites was undertaken to establish the basic passive principles for designing a sustainable shopping mall in Abuja, Nigeria as shown in Figure 2.9 below.

1. Planning aspects:
    - Site analysis
    - Building form
    - Building orientation
    - Landscaping
2. Building envelope:
    - External wall
    - Thermal insulation
    - Roof
    - Windows
        - Size
        - Orientation
        - Shading device
        - Natural ventilation
        - Daylight

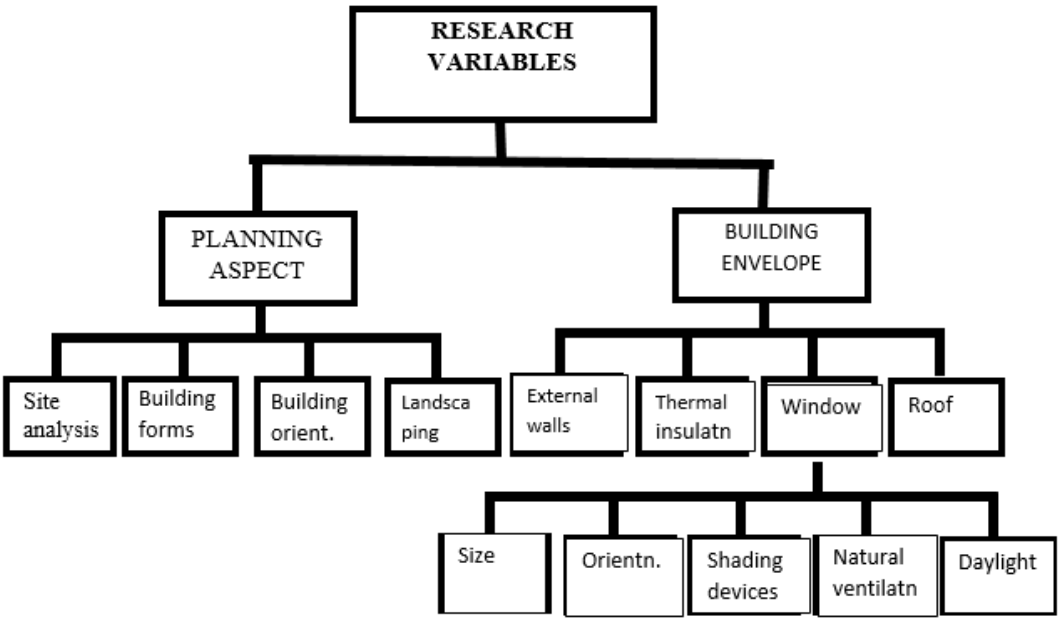


Figure 2.9: **Energy Efficiency Design Approach**

Source: Author (2017)

2.9.1 Planning Aspects

Planning aspect could be broken down into site analysis (viz: wind break, Shade from existing buildings and trees), building forms, building orientation, landscaping.

Site Analysis
Analysis of the building site should be made to determine the following:

- **Wind breaks**

Wind breaks are not desirable in tropical climates as they impede desirable breezes. Instead, it is desirable to have air movement. The planning authority of Abuja gives priority to the surrounding open green area for planting of trees which will serve as wind breaks.

- **Shade from existing buildings and trees**

The building can be sited to the east of such feature to reduce solar gain during afternoons when the sun is low. (UNEP, 2006) Warns that improper planning of the site can result in heat island effect. Such effects according to (UNEP, 2006) can be alleviated by reducing the total paved area on the site and shading the paved surfaces.

Building Form

Gut and Ackerknecht (1993) have suggested forms with large surfaces rather than compact buildings as large surfaces favour ventilation and heat emission at night-time. The building forms should thus be open, outward oriented and built on slits. Givoni (1998) states that building form largely depends on whether the building is planned to be air-conditioned or if it is intended to rely on natural ventilation. He recommends a compact shape for the building dwelled by people who are determined to use air conditioners and open forms for naturally ventilated buildings. Compactness of the building minimizes the surface area of the building envelope, resulting in a reduction of the heat gain through the envelope.

Building Orientation

Properly oriented buildings take advantage of solar radiation and prevailing wind. According to

Gut and Ackerknecht (1993), the longer axis of the building should lie along east-west direction for minimum solar heat gain by the building envelope. Wong and Li (2007) performed field measurements and computational energy simulations to examine the effectiveness of passive climate control methods such as building orientation in residential buildings of Singapore. Their results state that the best orientation for a building in

Singapore with its tropical climate is for the longer axis of the building to lie along east-west direction. They also conclude that the cooling load for a building can be reduced to 8% -11% by following this orientation The passive design feature on orienting the longer axis of the building towards east- west direction, as suggested Wong and Li is not always possible, especially due to actual orientation of the site, that is, when the site itself is longer on the west and east sides. Such cases are outside the influence of the developer and the architect. In such cases, the west facade needs more attention because it heats up in the afternoon while the east side is less problematic as it warm only in the morning.

Landscaping

Raeissi and Taheri (1999) acknowledged the beneficial effects of trees. They state that plantation of trees can result in energy saving, reduction of noise and pollution, modification of temperatures and relative humidity and psychological benefits on humans. Their study on proper tree plantation for energy saving concludes that the cooling loads of a house can be reduced by 10%- 40% by appropriate tree plantation. They also note that trees can act complementary to window overhangs, as they are better for blocking low morning and afternoon sun, while overhangs are better barriers for high noon sunshine. The study by Simpson and Mcpherson (1996) is in agreement with that of Raeissi and Taheri (1999). Simpson and Mcpherson (1996) have shown that tree shades can reduce annual energy for cooling by 10% -50%.

2.9.2 Building Envelope

Building envelope could be broken down into external wall, thermal insulation, roof, and window (viz: size, orientation, shading devices, natural ventilation and daylight).

External wall

As the main goal in building design for hot dry climates is reduction of direct heat gain by radiation through openings and reduction of internal surface temperature, the building should be designed with protected openings and walls Gut and Ackerknecht (1993). The walls can be protected by designing the roof so that it extends far beyond the line of walls and has broad overhanging eaves. Gut and Ackerknecht (1993) argue that the outer surface of the external wall should be reflective and light coloured. The findings by (Cheung, Fuller, & Luther, 2005) also support Gut and Ackerknecht's views on reflective and light coloured external walls. (Cheung, Fuller, & Luther, 2005) Had conducted a study to reduce the cooling energy for high-rise apartments through an improved building envelope design. They had identified six passive thermal design strategies, namely**, insulation, thermal mass, colour of external walls, glazing systems, window size and shading devices**. Their study shows that annual cooling has an almost linear relationship to the solar absorptance (amount of solar energy that passes into a material) of the external surfaces. Energy savings were found to be high with lower solar absorptance. A 30% reduction in solar absorptance can achieve a 12% saving in annual required cooling energy. They concluded that 12% saving on cooling energy could be obtained from using white or light colour external wall finishes.

Mathur and Chand (2003) believe that thermal resistance of a wall can be increased by introducing an air cavity. Similarly, Mallick (1996) asserts that variation in wall thickness can make a considerable difference in the comfort level of houses in tropical climates. The field measurements and computational energy simulations to examine the effectiveness of passive climate control methods such as facade construction in a typical 14 storey

residential building of Singapore by Wong and Li (2007) depict similar views as of Mallick (1996). Wong and Li (2007) from their study concluded that the use of thicker construction on east and west external walls can reduce the solar radiation heat gain and hence, the cooling load can be reduced by 7%-10 % when the thickness of external wall is doubled (i.e 450 mm concrete hollow block instead of 225 mm concrete hollow block).

Thermal insulation

According to Bollatturk (2008) thermal insulation is one of the most effective energy conservation measures for cooling and heating in buildings because it reduces heat transfer to and from the buildings. However, this view portrayed by Bolatturk (2008) seems to conflict with those of Gut and Ackerknecht (1993) and Yang and Hwang (1993). They state that thermal insulation has very little efficiency in warm–humid zones because the ambient air temperature inside and outside the building is same due to the free flow of air. Yang and Hwang (1993) have added that in warm and humid regions, condensation might occur and this would demean the thermal performance of the building envelope and cause mildew problems. Moreover, Gut and Ackerknecht (1993) also note that thermal insulation has a dual nature. It reduces daytime excess heat entering a building, but averts the building from cooling down at night. This dual nature makes insulation unsuitable for buildings with natural climate control. These contradictions need to form a consensus. Perhaps the solution lies in first determining the cooling load at the design stage and then deciding whether this cooling load would be reduced by employing thermal insulation in the building or by using passive means of control. (Tham, 1993) Study the various energy conservation strategies obtained results that do not encourage wall insulation. The study concludes that by adding 50 mm of polystyrene as wall insulation, only 1.7 % reduction in total energy use is

achieved. This suggests that if savings in operation cost were compared to the cost of installation, wall insulation would not be economically feasible. This finding, yet again conflicts with the results of Bolatturk (2008) and Cheung (2005).

Roof

The roof is an important element of design when it comes to conserving energy because this part of the building receives most of the solar radiation and its shading is not easy. Vijaykumar, Srinivasan and Dhandapani (2007) claim that concrete roofs in single or two storey buildings with 150 mm thickness of Reinforced Cement Concrete (RCC) and a Weathering Course (WC) having 75–100 mm thick lime brick mortar, account for about 50%- 70% of total heat transmitted into the occupant zone. Tang & Etzion (2004), conclude that the heat entering into the building structure through roof is the major cause for discomfort in case of non-air-conditioned building. However, Gut and Ackerknecht (1993) argue that this is true for single storied buildings and the top floor of multi-storied buildings. Gut and Ackerknecht (1993) also suggest that roofs should have large overhangs to protect the walls and openings from radiation and precipitation; they should be made of lightweight materials with a low thermal capacity and high reflectivity. Gut and Ackerknecht (1993) claim that roofs cannot be kept cool if there are any obstructions that prevent the airflow along the roof surfaces. They recommended that parapet walls along the roof should not be high and solid and should not create a stagnant pool of hot air. However, Gut and Ackerknecht do not indicate figures to explain how much they actually mean by ‘high’.

Alvarado and Martinez (2008) studied the impact of a simple and passive cooling system in reducing thermal loads of one storied roofs. Their results demonstrate that the alumunium

polyurethane insulation system with an optimal orientation reduces the midpoint temperature of a cement-based roof significantly. The results also exhibit that the roof insulation system can reduce the typical thermal load by over 70% while effectively controlling thermal fluctuations. However, Grade, Adelard and Boyer (2004) and Suehrche, Peterson and Selby (2008) have differing views. Grade, Adelard and Boyer (2004). Found that in tropical climates, intermediate roof insulation can only decrease the air temperature inside a dwelling by few degrees. Suehrche, Peterson and Selby (2008) concludes that roof insulation may hinder the desired night-time cooling. Vijaykumar, Srinivasan and Dhandapani (2007) has shown that passive roof cooling systems like coating the rooftop with highly reflective coatings can reduce the heat transmission across the roof by 20% – 70%. However, the deterioration of roof coating reflectivity over time is a major setback.

Wong, Tay, Wrong and Sia (2003) in their study on life cycle cost analysis of rooftop gardens in Singapore state that despite the availability of materials and suitability of climate in Singapore, many developers are often held back from including rooftop gardens in the design brief mainly by concerns pertaining to initial costs. In their study, life cycle cost analysis of two major roof types; inaccessible and accessible have been assessed. Accessible roof gardens are known as intensive green roofs and are found in Singapore's local building developments. These roof gardens are accessible by people and are used as parks or building amenities. Hence, they usually incorporate paving and seating areas. Their increased weight, higher capital cost, intensive planting and higher maintenance requirements characterize intensive green roofs. Inaccessible roof gardens, on the other hand, are known as extensive green roofs. They are not designed for public use; instead they are mainly developed for aesthetic and ecological benefits. They are distinguished by

being low cost, lightweight (50–150 kg/m2) and with thin mineral substrates. Minimal maintenance is required and inspection is performed one to two times per year. Wong, Tay, Wrong and Sia (2003) have estimated that the initial cost of extensive roof system, intensive green roof (shrubs) and intensive green roofs (trees) are $89.86, $178.93, $197.16/m2, respectively, while that of exposed flat roofs and built-up roofs are $49.35 and $131.60/m2. Their findings imply that the initial costs of roof gardens vary with the type of structure and on the selections of plantings placed on the rooftop. Their calculations show that only extensive green roofs bring about positive net savings. They argue that even though extensive green roof costs much higher initially, the life cycle cost is greatly reduced. The simulations results of the study conducted by Wong, Tay, Wrong and Sia (2003) reveal that an extensive green roof could reduce energy use of the building and achieve a net savings of 14.6%. Net energy savings of intensive green roof is not more than 4% and is therefore not significant. They also conclude that by considering these energy savings, extensive green roof does not cost more than conventional flat roof. The energy saving mentioned for both green roofs is likely to be dependent on the number of storeys, but, the authors do not point out the number of storeys in each type of building with the roof gardens. Wong, Tay, Wrong and Sia (2003) also states that even though first costs of green roof range from three to six times the cost of a typical roofing system, in the long-term, green roofs may be less expensive and outperform conventional roofing. Lippiatt and Boyles (2001), in favour of green roofs, note that a short-lived, low first-cost product is often not the cost-effective alternative. According to them, a higher first cost may be justified many times over for a durable product with minimal maintenance.

Despite the benefits that have been discussed about roof gardens, there are disadvantages of roof gardens that need to be considered before they are planned. Gut and Ackerknecht (1993) have reflected upon the following disadvantages of roof gardens:

- They add a heavy load on the roof structure.
- Reliable waterproofing of the roof is not easy to achieve.
- Roof gardens reduce heat emission at night.
- Draining channels and outlets may get clogged.
- High water use of roof gardens should be considered in regions with scarcity of water.

Windows

Windows could be broken down into size of window, orientation, shading device, natural ventilation and daylight.

Size

Openings are important design elements for admitting daylight, air flow, providing cross ventilation and views. Gut and Ackerknecht (1993) recommend that windows should be large and fully openable, with inlets of a similar size on opposite walls for proper cross-ventilation. Liping, Hien and Shuo (2007) claim that ventilation and indoor air quality can be improved by increasing the window to wall ratios (WWR), but it would also increase solar heat gain. There has always been a conflict with daylight provision and exclusion of solar penetration in designing windows. Liping, Hien and Shuo (2007) Carried out an optimized and comprehensive evaluation using building simulation and indoor CFD (computational fluid dynamics) simulation for an accurate prediction of indoor thermal

environment for naturally ventilated buildings in the hot-humid climate of Singapore. The window size in this coupled simulation was made to vary from WWR= 0.1 to WWR= 0.4 for all orientations. Their results show that the optimum window to wall ratio is equal to 0.24 and horizontal shading devices are needed for the four orientations, especially for large windows.

It should also be noted that Mathur and Chand (2003) argue that that rooms in which identical windows are on opposite walls, the average indoor air speed increases rapidly with the increase of the width of window, up to about 2/3 of the wall width; beyond that, the increase in air speed is in much smaller proportion.

Orientation

Gut and Ackerknecht (1993) note that openings in hot and humid regions should be placed according to the prevailing breeze so that air can flow through the internal space. Liping, Hien, and Shuo (2007) Also emphasize on avoiding east or west facing rooms for the purpose of thermal comfort and energy use.

Shading Device

Watson and Labs (1993) categorized shading devices into three categories namely solar transmittance of glazing materials, interior shading and exterior window shades. Solar transmittance is defined as the heat admitting or rejecting characteristic of the glazing materials. Watson and Labs (1993) and Gut and Ackerknecht (1993) advice against heat absorbing, heat reflecting and tinted glazing. According Watson and Labs (1993) heat absorbing clear and tinted glazing reduces solar transmission by absorbing heat within the material itself. They state that the absorbed heat can be uncomfortable to occupants because

it adds heat to the interior by conduction and thermal radiation. They also state that another disadvantage of heat absorbing and heat reflecting glazing types is that they block needed solar gain in winter and summer solar irradiation. Most of these glasses as Gut and Ackerknecht (1993) claim are limited in their effectiveness because their own temperature is raised, which increases the heat converted and reradiated into the internal space, or they tend to reduce light rather than heat.

Cheung, Fuller and Luther (2005) studied the effects of shading devices (overhangs and wing walls) along with five other passive design strategies on the cooling load for an apartment. The length of the overhang and wing wall were 1.5 metres each. Their results suggest that the longer the shading, the greater the reductions in both annual required cooling energy and peak cooling load.

Wong and Li (2007) used horizontal shading devices of lengths 0.3m, 0.6m and 0.9 m on both east and west facades of 14-storied building to study the effect on cooling load. Their results show that 3%, 7% and 10% energy can be saved by using 0.3 m, 0.6 m and 0.9 m respectively on east facades of the studied building. Similarly, 3%, 6% and 9% energy can be saved by using 0.3m, 0.6 m and 0.9 m respectively on west facades of the studied building. This study by Wong and Li (2007) considers east and west orientations but does not consider other parameters such as width of the opening, height of the openings, horizontal shadow angle and vertical shadow angle.

Natural Ventilation

Ventilation is the movement of air. According to Watson and Labs (1993), ventilation has three useful functions in the building sector. It is used to:

- Satisfy the fresh air needs of the occupants
- Increase the rate of evaporative and sensible heat loss from the body
- Cool the building interior by an exchange of warm indoor air by cooler outdoor air.

Watson and Labs (1993), explain that natural ventilation can be generated by the following two forces.

- Temperature difference between the outdoors and the indoors (thermal force).

  When a mass of air inside the room is heated, it expands and becomes less dense and rises. If openings are provided at different heights on the building's envelope, the indoor pressure is higher at the upper opening and lower at the lower opening. These pressure differences generate an inward flow at the lower opening and an outward flow at the upper one. When thermal forces discharge air from a building, the action is termed as stack effect.

- Wind flow against the building (wind pressure force).

  As wind blows against a building, the air in front of the building is compressed and creates a pressure zone. The air next to the leeward wall and above the roof expands and the pressure is reduced, creating a suction zone. These pressure differences between any two points on the building's envelope determine the possibility for ventilation when openings are provided at these points (driving force) and if air can flow inside the building through openings with the higher pressure to openings exposed to a zone with lower pressure. Cross- ventilation is defined as the situation in which outdoor air can flow in through inlet openings, located in the pressure zone, and flow out via outlet openings located in the suction sections of the building.

Another common natural ventilation and thus cooling technique is the use of atria and courtyards. A study of courtyards by Ali (2007) in Dhaka uses two typologies of six storied residential apartments, namely, the courtyard type and the non-courtyard type for comparison of thermal data. The results of this comparative analysis reveal that the buildings with courtyards are much more comfortable and thus desirable for the dwellers of Dhaka. However, due to constricted plot sizes, the dimensions of courtyards are such that they portray more as light well rather the true essence of courtyards. Furthermore, studies by Adwoud and Clark (2008) and Safarzadeh and Bahadon (2005) show that courtyards can reduce the cooling energy needs of single-storey buildings by only a relatively small amount.

Daylight

Krarti, Ericson and Hillman (2005) conducted a simplified analysis method to evaluate the potential of day lighting to save energy associated with electric lighting use in commercial buildings. Performance of day lighting were investigated for several combinations of building geometry, window opening size, and glazing type for four geographical locations in the United States. Their simulation results indicate that day lighting saves 31% of the total annual energy use from the artificial lighting system.

2.10 Summary of Energy Saving Features

Building Orientation: 8%-11% energy saving (Wong & Li 2007)

Landscaping: 10%-11% energy saving (Raeissi & Taheri 1999)

External wall: 30% reduction solar absorbance 12% saving in annual required cooling energy (Cheung, Fuller & Luther 2005)

White or light colour: 12% energy saving (Cheung, Fuller & Luther 2005)

Use of **thicker construction** on the east and west of the external walls: 7%-10% energy saving (Wong & Li 2007)

Thermal insulation: 1.7% of energy saving Tham (1993)

Roof: green roof 14.6% energy saving (Wong, Tay, Wrong & Sia 2003)

Horizontal shading device of length 0.3m, 0.6m, 0.9m. Will saves 3%, 7%, and 10% of energy (Wong & Li 2007)

Day lighting: saves 31% of the annual energy use from the artificial lighting system (Krarti, Ericson, & Hillman 2005).

CHAPTER THREE

3.0 Research Methodology

3.1 Case Study Approach

A case study approach is adopted for this research to evaluate the passive design features used in shopping mall design. According to Meyer (2001), the approach enables the researcher to study many different aspects, examine them in relation to each other and view the process within its total environment. Yin (2013) argues that a case study is an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries are not clearly stated. Unlike many other forms of research, the case study approach makes use of multiple methods of data collection such as interviews, document reviews, archival records, direct and participant observations etc. Yin (2013). However to be seen in its full sense, the study should include detailed documentation of information on the history and environment of study Oluigbo (2010). Hence, the case study to be carried out on this research will be documented based on the following headings: history and background, planning aspect (building form, building orientation, landscaping.) building envelope (external walls, thermal insulations, building materials, roof, windows, (size, orientation, shading device, natural ventilation, daylight)). This will then be followed by the application of general data collection technique.

3.2 Population of Study

Population of study comprises the totality of all shopping malls located within heart of Abuja, Nigeria that have a set of specifications and characteristics that are of interest to the researcher and to whom the research results can be generalized (Polit & Hungler, 1999). There are seven (7) malls located within the heart of Abuja, these include; Ceddi Plaza,

Dunes Centre, Silverbird Entertainment Centre, The Capital Hub, Jabi Lake Mall, Grand Towers Abuja Mall, Grand Square.

3.3 Case Study Selection

Oluigbo (2010) mentioned that for cases to be identified, they have to possess some intrinsic virtues which are in relation with the phenomenon under consideration. Hence, to properly select case studies best suited for this research, the following criteria are considered.

- **Its function:** Does the building function as a shopping mall?
- **The climatic zone to which the case belongs:** Does building falls within Hot-humid climate region of Nigeria?
- The scope of facility provided: this is to check the services, facilities, architectural characteristics, etc provided and its correlation to the proposed facility.
- Their adaptation to sustainable design strategies: this is to check its success as it relates to energy conservation/efficiency (in materials used, energy sources, passive design features etc.).

From the listed criteria above, the following cases were selected due to their inherent qualities which were in consonance with the phenomenon under investigation;

- Cedi Plaza Abuja
- Silverbird Entertainment Centre Abuja
- Jabi Lake Mall

The above case studies were also chosen deliberately to increase the likelihood of showing or expressing important variations of several features of the facility. This type of case study is illustrative. It is information-rich and can be used to illustrate an architectural style or issue.

3.4 Instruments of Data Collection

Various sources were selected for this research including: field/visual survey, interview, checklist, photographs, sketches and notes and simulation of case studies.

- **Field/Visual survey:** This is a method of data collection in which the eyes is used to study and observe. This survey must be guided by critical literature review guidelines. E.g. checklist. Visual survey can be documented through tabulation, sketches, plates, figures, written reports, etc.

- **Interview:** This is a method of data collection which involves preparing a list of interview schedule and laid down questions to ask the interviewee. It is grouped into three main types namely: structured, semi-structured and unstructured interview (Neville, 2007).

- **Checklist:** This is in form of field forms outlining the variables of passive design feature. It contained the list of variables which were observed and noted during the survey.

- **Photographs:** Photographs were taken to support the notes taken during the visit and for record. The photographs also provided a significant source of visual data about the case to outside observers. The photographs of relevant areas were taken in

order to show the passive design features on the cases possessed as well as the extent to which they were applied.

- **Sketches:** Sketches showing the selected case studies were made during the field survey. These sketches were considered vital to form an opinion on the physical setting and spatial organization of the case studies in order to explain the research.

- **Notes:** This instrument of data collection was adopted to back-up information discussed during the interview and what was observed during the field survey. Comprehensive notes were prepared as an ongoing record of what was happening as the research progressed.

- **Simulation of Case Studies:** Simulation is used in situations where it would be difficult normally to solve problems analytically and typically involves the introduction of random variables. In order to evaluate the data collected, the case study of Cedi plaza Abuja and Silverbird Galleria Abuja (case study 1&2) was modeled to analyze the non-physical variables with the aid of Autodesk ECOTECH software. In determining the energy consumption of a shopping mall, the following non-physical variables were considered, they are:

Temperature: Heating/Cooling loads, the hot-dry climate acquires high temperature during the day and low evening sun, it also depends on the season.

Annual energy consumption: This is the total amount of energy that the building will consume annually only at the operational phase.

3.5 Procedure of Data Collection

The data is collected through multiple instrument of data collection. All the selected case studies are visited by the researcher for field survey, interviews were conducted, photographs were taken, notes and sketches were collected. The field survey involved visual survey of all passive design features employ on the case studied buildings. The researcher in this case observed the principles of passive design features qualitatively using checklist. List of variables in the checklist were checked and assessed sequentially.

During the interview, the researcher adopted a semi-structured interview guide where questions were asked and the answers were taken as notes by the researcher. Data was also recorded on audiotape to enrich the interview. However, permission to use tape recorder was sought before the interview and all the participants agreed to it. The tape recorder was tested before the interview; it was positioned close to both the researcher and the interviewee to record the conversion. While the interview was going on, notes were also being taken to back-up the discussion. Final notes were also prepared after the interview was concluded. All the interviews lasted for less than an hour. After each interview was concluded, a reflective interview notes were made. The recorded interview was subsequently transcribed into Microsoft Word by the researcher for the purpose of the study.

In cases where were no documentation available for the architectural drawings, the buildings were surveyed and the drawings were prepared by the researcher through sketches, photographs and notes. All photographs were taken either by the author or with help of relatives and friends. Photographs of relevant areas of the case studies were taken in order to highlight the observed passive design features. Sketches showed the spatial

organization of some of the study cases while notes explained the observed passive design features in each of the selected cases. Finally a simulation of Cedi plaza Abuja and Silverbird Entertainment Centre Abuja (i.e case study 1&2) were drawn, modelled and analysed with the aid of Autodesk ECOTECT software to test for the non-physical variables i.e. annual energy consumption.

3.6 Data Analysis

According to Polit and Hungler (1999), analysis of qualitative data is an active and interactive process and data analysis means to organize, to provide structure and elicit meaning to the data obtained. The theoretical background of the study provides the basis of the method used for analysing the content. For this research, the analysis was first focused on the individual interviews, then the field survey carried out. The data is then analysed and compared the results to identify the application of passive design principles in each selected cases**.**

Data analysis was based on descriptive, visual and ranking system. A checklist was also employed to assess and record the extent to which passive design features were employed in the three shopping malls based on a 5 point scale ranking system ranging from 1 point = Poor, to 5 point =Excellent as shown in Table 3.1a and 3.1b. And finally a simulation of Silverbird Galleria Abuja and Cedi plaza Abuja (i.e. case study 1&2) was modelled and analysed with the aid of Autodesk ECOTECT software to test for the non-physical attribute i.e. energy consumption.

Table 3.1a: **Checklist for Case Study Variables**

S/N	Variables	Check list	Scale Factor (Level of Application) 1 2 3 4 5	Remark
1.	**Planning Aspect**			
	• Site Analysis	Availability of wind breaking features Shade from exiting building & tress		
	• Building form	The building form in relation to passive design. i.e. It Surface Area to Volume		
	• Building orientation	The orientation of the building The actual orientation of the site		
	• Landscaping	Appropriate tree plantation The use of impervious surfaces		
2.	**Building Envelope**			
	• External wall	Appropriate overhanging Eaves to shade the external walls The use of Light colour surfaces The use of air cavity within the walls Variation of wall thickness especially on East and west external walls. (Wong and Li 2007)		
	• Thermal insulation	The use of thermal insulation material use on the external walls especially on East and west orientation and the ground floor slab.		
	• Roof	The use of Lightweight materials with a low thermal capacity and high reflectivity Sufficiency of air flow within the roof Height of the parapet walls to prevent stagnant pool of hot air The use of roof insulation system The use of roof top coating with high reflective coating and a lighter roof colour.		
	Windows			
	• Size	Appropriate window sizes		
	• Orientation	The placement of opening should be placed according to the prevailing breeze		
	• Shading devices	The horizontal shading devices should be of lengths 0.3m, 0.6m,0.9m on both east and west facades , (Wrong and Li, 2007)		
	• Natural ventilation	Design measures to prevent Stack effect (thermal forces)		

Table 3.1b: **Checklist for Case Study Variables**

S/N	Variables	Check list	1	2	3	4	5	Remark
	• Day lighting	The location of the window with respect to the pressure zone The use of atrium and courtyard The building geometry The size of the window openings The glazing type						

SCALE FACTOR: 1= Poor, 2= Fair, 3= Average, 4= Good, 5=Excellent

Source: Author (2017)

The scale factor indicates the level of application of passive design features on the case study buildings;

1-Poor= Total absence of passive design features

2-Fair= Not adequately applied and not performing it function

3-Average=Not adequately applied but performed it functions

4-Good =Adequately applied but not performing as expected

5-Excellent= Adequately applied and performing as expected

CHAPTER FOUR

4.0 Data Presentation and Analysis

4.1 Ceddi Plaza Abuja

Ceddi Plaza is owned by Ceddi Corporation and is located in the Central Business Area of Abuja. The Plaza consists of 10,000 square meters of retail and office space. The tenant mix is made up of three floors of retail (eateries, fashion boutiques, entertainment and services) and three floors of corporate office space. Nigerian owned and designed, the mixed use facility is managed by Broll Property Services Nigeria. Opened officially in November 2005, the Plaza is celebrated as the premiere Centre for Shopping and Entertainment in the City of Abuja.

It has an inward orientation and offers an interesting contrast to the landscaping that heralds the pedestrian access on the approach street level. Members of the public would be dropped off at the car porch by the main entrance, while all cars are parked in the basement and street level car parks. There are two staircases and two lifts from the car park to the main entrance level or any other floor in the development. The main entrance foyer opens into the giant circular atrium, traversing the entire six floors with twin panoramic lifts framing the grand staircase. This main atrium is connected to the other two atria of the three shopping levels through the mall. The attractions for the shopping centre are the restaurant, the departmental store, the cinema and the café. The grand staircase terminates at the first floor and celebrates the access to the department store on the ground floor. Additional shops makes up the first floor, while an up market restaurant will complement the theatre on the second floor, other facilities includes a gym and service shops such as hairdressing and beauty salons and a laundry and dry-cleaning outfit. The second to third floors are open

plan offices with provision for voice and data outlets this will ensure that the offices can offer tenants the latest technology. The penthouse office on the 4th floor is designed for maximum visibility.

4.1.1 Ceddi Plaza Entertainment Profile

3 Eateries, 17 Fashion and Accessories, 1 Entertainment, 1 Furniture Store, 5 health and Beauty, 2 Grocery Store and wine store, 3 Telecomms, Electronics and phones, 4 Childrens Shops and Kiosks, 5 Services, 2 Offices. Plate XI shows a pictorial view of Ceddi Plaza Abuja.



Plate XI: **Ceddi Plaza Abuja**

Source: Field Survey (2016)

Planning aspects:

Site analysis: The site is located at the Central Business District of Abuja and surrounding the site there is no visible wind break features such trees, but rather there are surrounding a building which serves as wind breakers and shade from the effect of solar heat gain.

Building form: the building has a large surface area when compared to its volume ratio which favours ventilation and heat emission at night, it also encourages direct solar gain through the building envelope which in turn increases the energy demand on the building. The building has a compact shape which is originally design to be cool through mechanical means. Plate XII shows the surrounding view of Ceddi Plaza.



Plate XII: **Surrounding View Ceddi Plaza**

Source: Field Survey (2016)

Building orientation: The building was not properly oriented to take advantage of solar radiation and the prevailing wind i.e. the longer axis of the building does not lie exactly on the east-west direction rather it is tilted to about 120^0 from the north this maximize the heat gain through the building envelope. The tilting of the building is as a result of the actual

orientation of the site, the site is small when compared with the building, which occupies about 75% of the total land space. As shown in Figure 4.1.

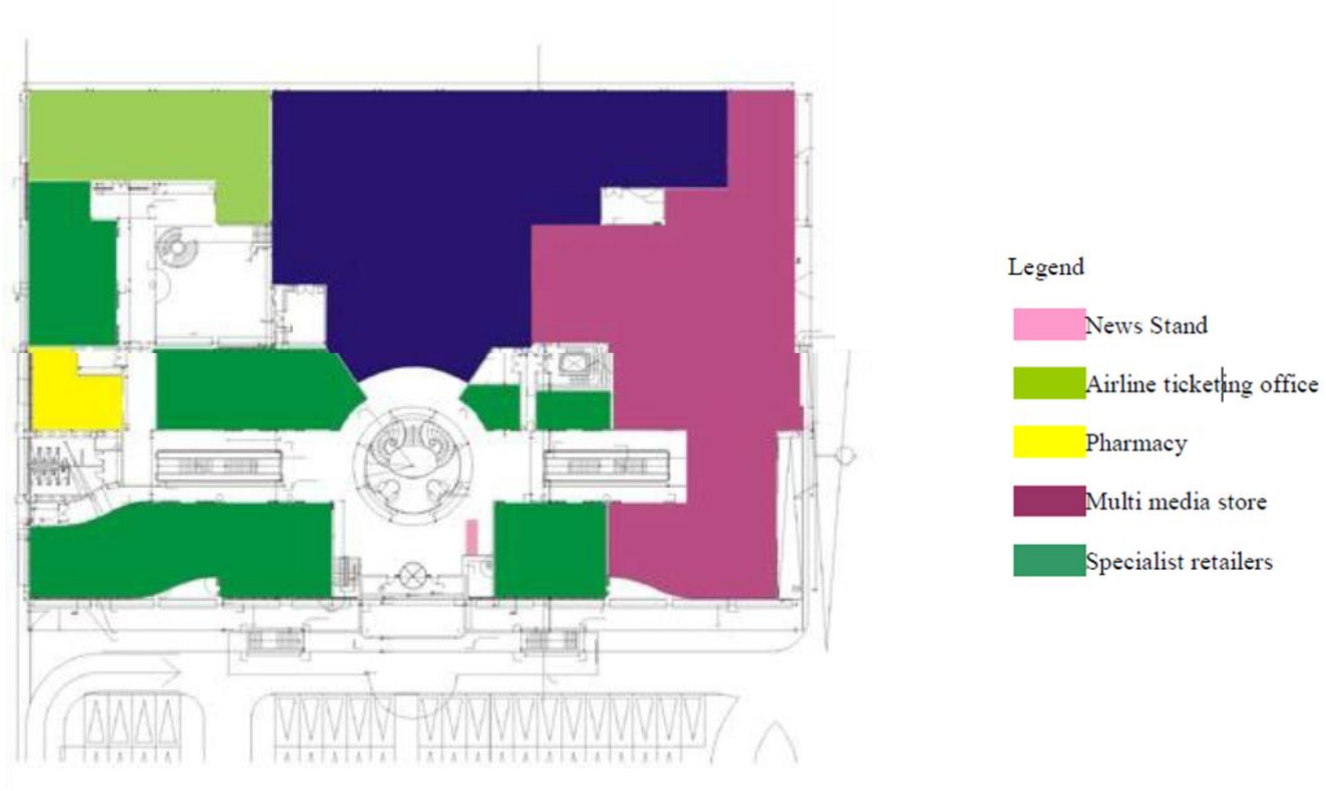


Figure 4.1: **Ground Floor Plan Ceddi Plaza**

Source: Field Survey (2016)

Landscaping: The building used up about 75% of the total land space making landscaping difficult and the floor coverage area is less than the standard examples of the hard and soft landscape elements employed on the facility which includes pedestrian paved way, street level parking spaces kerbs lighting features, sculptures and water fountain the soft elements includes green areas and plants which include trees of various species etc.

Building envelope:

External wall: The external walls of the building was made of a concrete block render which gains a lot direct solar radiation through the building fabric and increases internal surface temperature. The colour of the building is not light and reflective as it supposed to be, i.e. the lighter the colour the less the rate of solar heat gain through the building fabric. The external walls have neither air cavity nor a thermal insulating material to curtail the direct solar radiation.

Roof: The roof of the building was made of reinforced concrete deck roof with asphalt which causes a lot of discomfort in the case of non-air-conditioned building. The asphalt covering makes the colour of the roof more receptive to direct solar radiation. Because the roof was made up reinforced concrete slab there is no provision for air flow within the roof which causes stack effect within the building interior. The heights of the parapet walls are okay which does not create stagnant pool of hot air around the roof surfaces. Roof insulation system was not use.

Windows: The window of the building was made of double glaze glass with aluminium frame, and the opening of the windows are placed towards the prevailing breeze, neither horizontal nor vertical shading devices were applied on the building to shade the windows, which expose the window to more direct solar radiation. The atrium was not large enough to prevent stack effect within the building interior.

MERIT

- The windows are well placed towards the prevailing breeze which aid ventilation.
- It has low parapet walls which prevent stagnant pool of hot air on the roof structure.

DEMERIT

- There is no visible wind breaking features within the landscape of the mall.
- Cavity walls and thermal insulations are not incorporated in the design of the external walls to reduce thermal conduction.
- The central atrium is not large enough to curtail the effect of stack effect within the building interior.
- There no presence of horizontal shading devices to shade the building.
- The ratios of hard and soft floor coverage for landscaping are not up to the required standard.

Table 4.1a and 4.1b below shows the checklist analysis of Ceddi Plaza, Abuja

Table 4.1a: **Checklist for Case Study 1 Variables (Ceddi Plaza)**

S/N	Variables	Check list	Scale Factor (Level of Application)					Score
			1	2	3	4	5	
1.	**Planning Aspect**							
	• Site Analysis	Availability of wind breaking features base on typology	■					**1/5**
		Shade provided from exiting building & tress			■			**3/5**
	• Building form	The building form in relation to passive design. i.e. It Surface Area to Volume		■				**2/5**
	• Building orientation	The orientation of the building			■			**3/5**
		The actual orientation of the site		■				**2/5**
	• Landscaping	Appropriate tree plantation		■				**2/5**
		The use of impervious surfaces		■				**2/5**
2.	**Building Envelope**							
	• External wall	Appropriate overhanging Eaves to shade the external walls	■					**1/5**
		The use of Light colour surfaces		■				**2/5**
		The use of air cavity within the walls	■					**1/5**
		Variation of wall thickness especially on East and west external walls. (Wong and Li 2007)	■					**1/5**

Table 4.1b: **Checklist for Case Study 1 Variables (Ceddi Plaza)**

S/N	Variables	Check list	1	2	3	4	5	Score
	• Thermal insulation	The use of thermal insulation material use on the external walls especially on East and west orientation and the ground floor slab.	■					**1/5**
	• Roof	The use of Lightweight materials with a low thermal capacity and high reflectivity		■				**2/5**
		Sufficiency of air flow within the roof	■					**1/5**
		Height of the parapet walls to prevent stagnant pool of hot air					■	**5/5**
		Height of the parapet walls to prevent stagnant pool of hot air					■	**5/5**
		The use of roof insulation system		■				**2/5**
		The use of roof top coating with high reflective coating and a lighter roof colour.	■					**1/5**
	Windows							
	• Size	Appropriate window sizes				■		**4/5**
	• Orientation	The placement of opening should be placed according to the prevailing breeze					■	**5/5**
	• Shading devices	The horizontal shading devices should be of lengths 0.3m, 0.6m,0.9m on both east and west facades , (Wrong and Li, 2007)	■					**1/5**
	• Natural ventilation	Design measures to prevent Stack effect (thermal forces)		■				**2/5**
		The location of the window with respect to the pressure zone			■			**3/5**
		The use of atrium and courtyard		■				**2/5**
	• Day lighting	The building geometry			■			**3/5**
		The size of the window openings			■			**3/5**
		The glazing type			■			**3/5**

SCALE FACTOR: 1= Poor, 2= Fair, 3= Average, 4= Good, 5=Excellent

Source: Author (2017)

Table 4.2 below shows the checklist frequency of scores analysis of Ceddi Plaza Abuja (case study 1)

Table 4.2: **Checklists Frequency of Scores Case Study 1**

CHECKLISTS FREQUENCY OF SCORES									
SCALE F./ VARIABLES	**Site Planning**	**Building Form**	**Building Orientation**	**Landscaping**	**External Walls**	**Thermal Insulation**	**Roof**	**Windows**	**TOTAL FREQ.**
Poor	1	0	0	0	3	1	2	1	8
Fair	0	1	1	2	1	0	2	2	9
Average	1	0	1	0	0	0	0	4	6
Good	0	0	0	0	0	0	0	1	1
Excellent	0	0	0	0	0	0	1	1	2

Source: Author (2017)

4.2 Silverbird Entertainment Centre Abuja

Silverbird Entertainment Centre Abuja is owned by Silverbird group and is located at plot 1161, Memorial Drive, By Musa Yar'adua Centre, Central Business District Abuja. Silverbird Entertainment Centre consists of 33,000 sq m retail space, luxury shopping, 12 screen cinema, VIP balconies, Food court, Spa, clothing, supermarket, lifestyle, entertainment etc. Silverbird Group was founded by Mr. Ben Murray-Bruce in 1980, and the company is today one of the largest media entertainment companies in Africa. Silverbird has become one of the most recognizable shopping mall brands, millions of people each year seek out the dynamic and fine shopping environment uniquely offered by Silverbird Malls. Silverbird Cinemas is currently the largest cinema chain in West Africa with more than 50 screens in Lagos, Abuja, Port Harcourt, Uyo and Accra, Ghana. The Abuja mall was constructed by ITB Construction Company in 2007 and was ready for use officially in 2009. The mall consists of a basement and 7 suspended floors, 10 escalators, 2 paranomic lift, 1 V.I.P lift, 1 cargo lift for services alongside with a service stair case, from the basement to the 3rd floor is purely shopping and from 4th to 6th floors comprises 12 screen cinemas rooms with a projection booth and a V.I.P gallery. The last floor which is

called the pent house is strictly private. It also has escape stair cases at strategic locations within the mall. The mall major anchor tenant is Shoprite. Plate XIII shows a pictorial view of Silverbird Entertainment Centre, Abuja.



Plate XIII: **Silverbird Entertainment Centre Abuja**

Source: Field Survey (2016)

Planning aspects:

Site analysis: The site is located at plot 1161, Memorial Drive, By Musa Yar'adua Centre, Central Business District Abuja surrounding the site there is no visible wind break features such trees, and surrounding buildings which may serves as wind breakers and shade from the effect of solar heat gain.

Building form: The building has a good surface area to volume ratio which favour ventilation and heat emission at night, it also encourage direct solar gain through the

building envelope which in turn increases the energy demand on the building. The building has a compact shape which is originally design to be cool through mechanical means. Plate XIV shows the surrounding view of Silverbird Entertainment Centre Abuja.



Plate XIV: **Surrounding view of Silverbird Abuja**

Source: Field Survey (2016)

Building orientation: The building was properly oriented which takes the advantage of solar radiation and the prevailing wind i.e. the longer axis of the building lies exactly on the east-west direction. The site orientation does affect the building orientation because the land was large enough to orient the building and still have some spaces for parking, vehicular and pedestrian circulation. Figure 4.2 shows the site floor plan of Silverbird Entertainment Centre, Abuja.

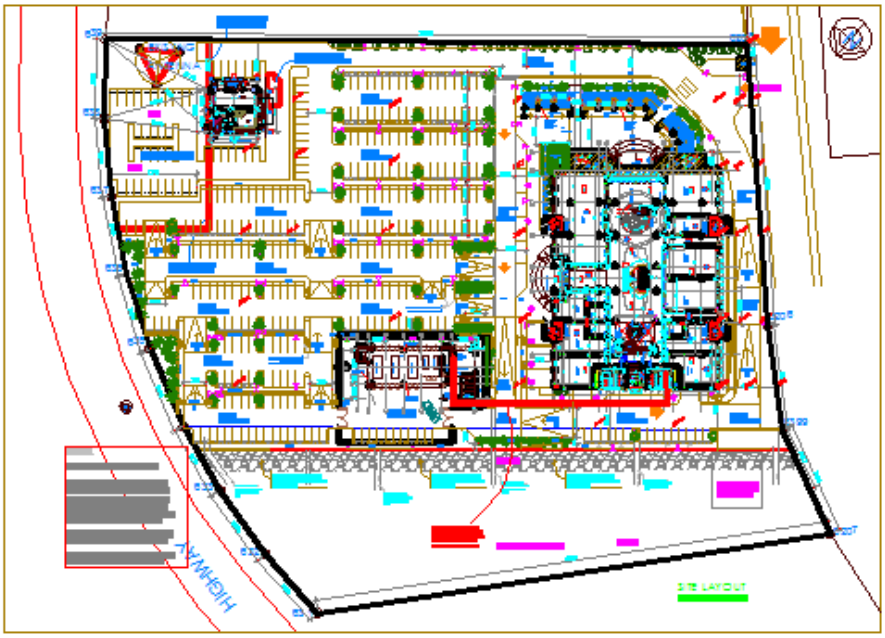


Figure 4.2: **Site Floor Plan of Silverbird Abuja**

Source: Field Survey (2016)

Landscaping: The building used up about 20% of the total land space making landscaping easier but the floor coverage area is less than the standard examples of the hard and soft landscape elements employed on the facility which includes pedestrian paved way, street level parking spaces kerbs lighting features, sculptures and water fountain the soft elements includes green areas and plants which include trees of various species etc., thus affect the micro climate of the site.

Building envelope:

External wall: The external walls of the building was made of a concrete block render which gains a lot direct solar radiation through the building fabric and increases internal surface temperature. The colour of the building is light and reflective i.e. the lighter the colour the less the rate of solar heat gain through the building fabric. The external wall has

no air cavity or a thermal insulating material to curtail the direct solar radiation. Plate XV shows the external view of Silverbird, Abuja.

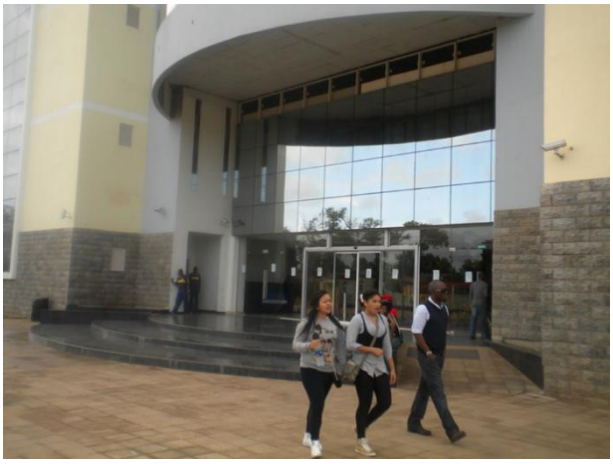


Plate XV: **External view of Silverbird Abuja**

Source: Field Survey (2016)

Roof: The roof of the building was partly made of reinforced concrete deck roof with asphalt and a pitch roof with corrugated aluminium sheets, as shown in figure 4.3 which causes a lot of discomfort in the case of non-air-conditioned building. The asphalt covering makes the colour of the roof more receptive to direct solar radiation. The pitch roof has sufficient headroom from the ceiling board which allows air flow within the roof; this reduces the rate solar radiation coming into the building. The heights of the parapet walls are okay which does not create stagnant pool of hot air around the roof surfaces. Roof insulation system was use.

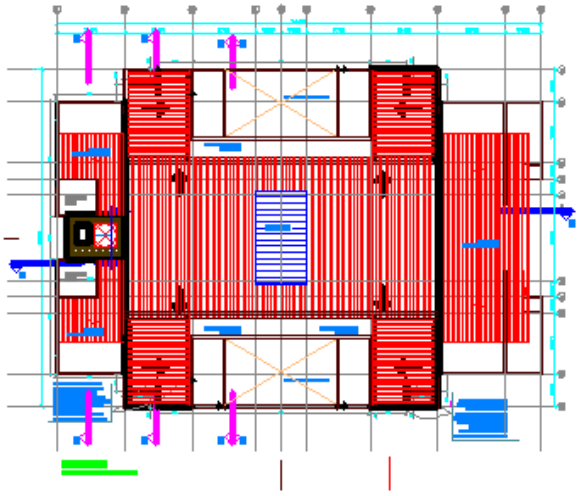


Figure 4.3: **Roof Plan of Silverbird Abuja**

Source: Field Survey (2016)

Windows: The window of the building is made up of double glaze glass with aluminium frame, and the opening of the windows are placed towards the prevailing breeze as shown on Plate XVI, neither horizontal nor vertical shading devices were applied on the building to shade the windows, which expose the window to more direct solar radiation. There was no provision for a central atrium that will be large enough to prevent stack effect within the building interior.

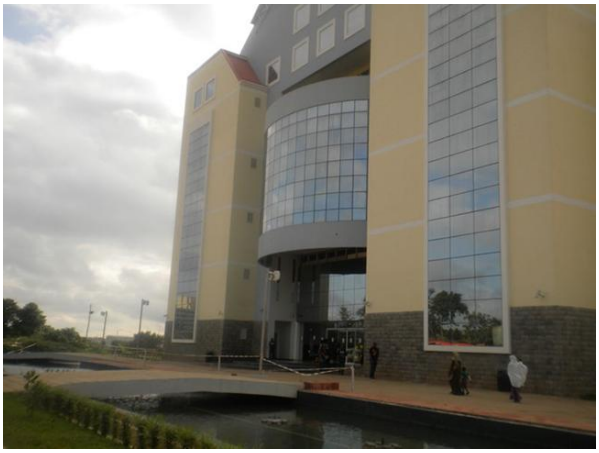


Plate XVI: **External view of Silverbird Abuja**

Source: Field Survey (2016)

MERIT

- The building is properly oriented
- The windows are well placed towards the prevailing breeze which aid ventilation.
- It has low parapet walls which prevent stagnant pool of hot air on the roof structure.
- Proper utilization of light colour surfaces to enhance passive cooling.

DEMERIT

- There is no visible wind breaking features within the landscape of the mall.
- Cavity walls and thermal insulations are not incorporated in the design of the external walls to reduce thermal conduction.
- The building is not design to prevent stack effect.
- There no presence of horizontal and vertical shading devices to shade the building.
- The ratios of hard and soft floor coverage for landscaping are not up to the required standard.
- Light colour roofing sheet was not used.

Table 4.3a and 4.3b below shows the checklist analysis of Silverbird Entertainment Centre, Abuja

Table 4.3a: **Checklist for Case Study 2 Variables (Silverbird Entertainment Centre Abuja)**

S/N	Variables	Check list	Scale Factor (Level of Application)					SCORE
			1	2	3	4	5	
1.	**Planning Aspect**							
	• Site Analysis	Availability of wind breaking features base on typology	■					1/5
		Shade provided from exiting building & tress		■				2/5
	• Building form	The building form in relation to passive design. i.e. It Surface Area to Volume			■			3/5
	• Building orientation	The orientation of the building					■	5/5
		The actual orientation of the site				■		4/5
	• Landscaping	Appropriate tree plantation		■				2/5
		The use of impervious surfaces			■			3/5
2.	**Building Envelope**							
	• External wall	Appropriate overhanging Eaves to shade the external walls	■					1/5
		The use of Light colour surfaces				■		4/5
		The use of air cavity within the walls		■				2/5
		Variation of wall thickness especially on East and west external walls. (Wong and Li 2007)		■				2/5
	• Thermal insulation	The use of thermal insulation material use on the external walls especially on East and west orientation and the ground floor slab.			■			2/5
	• Roof	The use of Lightweight materials with a low thermal capacity and high reflectivity		■				2/5
		Sufficiency of air flow within the roof			■			3/5
		Height of the parapet walls to prevent stagnant pool of hot air					■	5/5
		The use of roof insulation system			■			3/5
		The use of roof top coating with high reflective coating and a lighter roof colour.	■					1/5

Table 4.3b: **Checklist for Case Study Variables (Silverbird Entertainment Centre Abuja)**

S/N	Variables	Check list	1	2	3	4	5	SCORE
	Windows							
	• Size	Appropriate window sizes				■		**4/5**
	• Orientation	The placement of opening should be placed according to the prevailing breeze					■	**5/5**
	• Shading devices	The horizontal shading devices should be of lengths 0.3m, 0.6m,0.9m on both east and west facades , (Wrong and Li, 2007)	■					**1/5**
	• Natural ventilation	Design measures to prevent Stack effect (thermal forces)		■				**2/5**
		The location of the window with respect to the pressure zone			■			**3/5**
		The use of atrium and courtyard		■				**2/5**
	• Day lighting	The building geometry			■			**3/5**
		The size of the window openings			■			**3/5**
		The glazing type			■			**3/5**

SCALE FACTOR: 1= Poor, 2= Fair, 3= Average, 4= Good, 5=Excellent

Source: Author (2017)

Table 4.4 below shows the checklist frequency of scores analysis of Silverbird, Abuja (case study 2)

Table 4.4: **Checklists Frequency of Scores Case Study 2**

	CHECKLISTS FREQUENCY OF SCORES								
SCALE F. / VARIABLES	**Site Planning**	**Building Form**	**Building Orientation**	**Landscaping**	**External Walls**	**Thermal Insulation**	**Roof**	**Windows**	TOTAL FREQ.
Poor	1	0	0	0	1	0	1	3	6
Fair	1	0	0	2	2	1	1	0	5
Average	0	1	0	0	0	0	1	1	8
Good	0	0	1	0	1	0	1	4	4
Excellent	0	0	1	0	0	0	1	1	3

Source: Author (2017)

4.3 Jabi Lake Mall Abuja

The mall is owned by Actis and Duval Properties (known names in the Investment and Development circles) have joined forces to create the Jabi Lake Mall Development Company for the construction of Jabi Lake Mall which sits on 5 hectares of land overlooking the Jabi Lake. The mall is located on Bala Sokoto way off Mike Akhigbe way Abuja Nigeria, and was oriented facing scenic eastern shore of Jabi Lake, a natural body of water in the Jabi district of Abuja, the mall is only a ten-minute, 8km drive west of Abuja's business centre the mall is hard to miss, especially when coming over the Jabi Bridge. The Jabi Lake Mall happens to be one of the biggest and best mall in Nigeria thus far, it follows in the footsteps of other retail centres developed by Actis: the Palms, The Junction, Accra Mall and Ikeja City Mall. Opened in November 2015, the double level mall feature contemporary architecture, with vibrant colour and pattern concepts throughout. Restaurants, cafes and fast food outlets will surround a stunning triple height promotion court with a feature staircase. Outdoors, a lakeside boardwalk and entertainment area will offer a restaurant and café environment and exceptional views over the water. The mall has two retail levels consisting of 25,000m^2 and over 100 shops with Game and Shoprite each taking 5,000m^2. There will be a 5 screen cinema of 1,400m^2 operated by Silverbird, a food court on the first level, a children's entertainment area and a restaurant boulevard on the ground level facing the Jabi Lake with full accessibility from the boardwalk. Car parking for 733 cars was provided on both levels to offer shoppers access on either level, with a vehicle drop off area, bus stop and pedestrian footpaths connecting the mall to the main road make Jabi Lake Mall easily accessible, The tenant mix is a variety of local, national and international brands with Game, Shoprite and Silverbird cinemas. Plate XVII below shows a pictorial view of Jabi Lake Mall, Abuja.



Plate XVII: **Jabi Lake Mall Abuja**

Source: Field Survey (2016)

Planning aspects:

Site analysis: The mall is located on Bala Sokoto way off Mike Akhigbe way Abuja Nigeria, surrounding the site there is no visible wind break features such trees and surrounding buildings as shown on Plate XVIII, which may serves as wind breakers and shade from the effect of solar heat gain.

Building form: The building has a large surface area to volume ratio which favours ventilation and heat emission at night; it also encourages direct solar gain through the building envelope which in turn increases the energy demand on the building. The building has a compact shape which is originally design to be cool through mechanical means.



Plate XVIII: **External view of Jabi Lake Mall**

Source: Field Survey (2016)

Building orientation: The building was properly oriented which takes the advantage of solar radiation and the prevailing cool breeze from the lake as shown in Figure 4.4 i.e. the longer axis of the building lies exactly on the east-west direction. The site orientation does not affect the building orientation because the site has a wider north-south orientation and still have some spaces for parking, vehicular and pedestrian circulation.

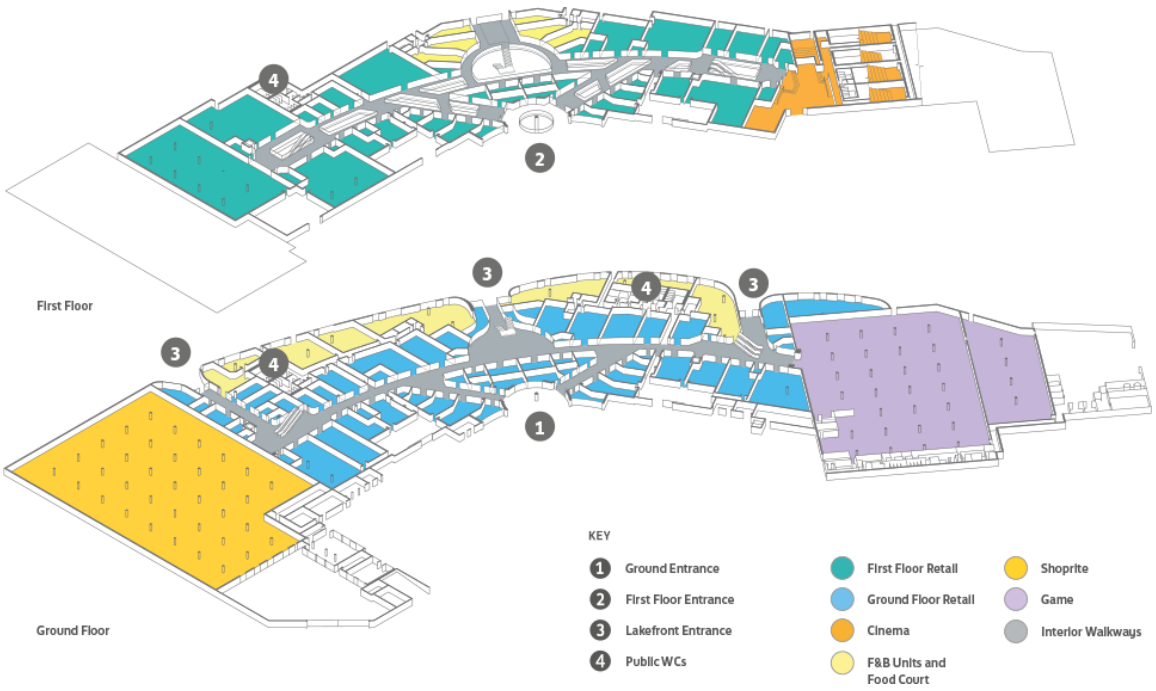


Figure 4.4: **Ground and First Floor Plans Jabi Lake Mall**

Source: Field Survey (2016)

Landscaping: The building used up about 50% of the total land space making landscaping quite difficult that is why two levels parking was design to cater for the parking requirement as shown on Plate XIX, on the other hand limiting the potential of the site in achieving the requirement for the floor coverage area in relation to the standard examples for the hard and soft landscape elements employed on the facility which includes pedestrian paved way, street level parking spaces kerbs lighting features, sculptures and water fountain the soft elements includes green areas and plants which include trees of various species etc., thus affect the micro climate of the site.



Plate XIX: **Perspective view of Jabi Lake Mall**

Source: Field Survey (2016)

Building envelope:

External wall: The external walls of the building was made of a reinforced concrete precast panels mix with concrete block render which gains a lot direct solar radiation through the building fabric and increases internal surface temperature. The colour of the building is light and reflective i.e. the lighter the colour the less the rate of solar heat gain through the building fabric. The external walls have neither air cavity nor a thermal insulating material to curtail the direct solar radiation.

Roof: The roof of the building was partly made of reinforced concrete deck roof with asphalt and a pitch roof with corrugated aluminium sheets which causes a lot of discomfort in the case of non-air-conditioned building. The asphalt covering makes the colour of the roof more receptive to direct solar radiation. The pitch roof has sufficient headroom from the ceiling board which allows air flow within the roof; this reduces the rate solar radiation

coming into the building. The heights of the parapet walls are okay which does not create stagnant pool of hot air around the roof surfaces. Roof insulation system was use.

Windows: The window of the building is made up of double glaze glass with aluminium frame, and the opening of the windows are placed towards the prevailing breeze, neither horizontal nor vertical shading devices were applied on the building to shade the windows, which expose the window to more direct solar radiation. There was no provision for a central atrium that will be large enough to prevent stack effect within the building interior. Clere-storey windows were use in the entire mall for natural lighting.

MERIT

- The building is properly oriented
- The windows are well placed towards the prevailing breeze which aid ventilation.
- It has low parapet walls which prevent stagnant pool of hot air on the roof structure.
- Proper utilization of light colour surfaces to enhance passive cooling.
- Good site location because of its closeness to the Jabi Lake which affect the micro climate of the site.

DEMERIT

- There is no visible wind breaking features within the landscape of the mall.
- Cavity walls and thermal insulations are not incorporated in the design of the external walls to reduce thermal conduction.
- The building is not design to prevent stack effect.
- There no presence of horizontal and vertical shading devices to shade the building.

- The ratios of hard and soft floor coverage for landscaping are not up to the required standard.
- The window to wall ratio (WR) is not adequate for proper ventilation.

Table 4.5a and 4.5b below shows the checklist analysis of Jabi Lake Mall, Abuja

Table 4.5a: **Checklist for Case Study 3 Variables (Jabi Lake Mall Abuja)**

S/N	Variables	Check list	Scale Factor (Level of Application)					SCORE
			1	2	3	4	5	
1.	**Planning Aspect**							
	• Site Analysis	Availability of wind breaking features base on typology	■					1/5
		Shade provided from exiting building & tress		■				2/5
	• Building form	The building form in relation to passive design. i.e. It Surface Area to Volume		■				2/5
	• Building orientation	The orientation of the building					■	5/5
		The actual orientation of the site				■		4/5
	• Landscaping	Appropriate tree plantation	■					1/5
		The use of impervious surfaces	■					1/5
2.	**Building Envelope**							
	• External wall	Appropriate overhanging Eaves to shade the external walls	■					1/5
		The use of Light colour surfaces					■	5/5
		The use of air cavity within the walls		■				2/5
		Variation of wall thickness especially on East and west external walls. (Wong and Li 2007)		■				2/5
	• Thermal insulation	The use of thermal insulation material use on the external walls especially on East and west orientation and the ground floor slab.		■				2/5
	• Roof	The use of Lightweight materials with a low thermal capacity and high reflectivity			■			3/5
		Sufficiency of air flow within the roof				■		4/5
		Height of the parapet walls to prevent stagnant pool of hot air					■	5/5
		The use of roof insulation system				■		4/5
		The use of roof top coating with high reflective coating and a lighter roof colour.			■			3/5

Table 4.5b: **Checklist for Case Study Variables (Jabi Lake Mall Abuja)**

S/N	Variables	Check list	1	2	3	4	5	SCORE
	Windows							
	• Size	Appropriate window sizes				■		**4/5**
	• Orientation	The placement of opening should be placed according to the prevailing breeze					■	**5/5**
	• Shading devices	The horizontal shading devices should be of lengths 0.3m, 0.6m,0.9m on both east and west facades , (Wrong and Li, 2007)	■					**1/5**
	• Natural ventilation	Design measures to prevent Stack effect (thermal forces)		■				**2/5**
		The location of the window with respect to the pressure zone			■			**3/5**
		The use of atrium and courtyard		■				**2/5**
	• Day lighting	The building geometry			■			**3/5**
		The size of the window openings			■			**3/5**
		The glazing type			■			**3/5**

SCALE FACTOR: 1= Poor, 2= Fair, 3= Average, 4= Good, 5=Excellent

Source: Author (2017)

Table 4.6 below shows the checklist frequency of scores analysis of Jabi Lake Mall, Abuja (case study 3)

Table 4.6: **Checklist Frequency of Scores Case Study 3**

	CHECKLISTS FREQUENCY OF SCORES								
SCALEF. / VARIABLES	**Site Analysis**	**Building Form**	**Building Orientation**	**Landscaping**	**External Walls**	**Thermal Insulation**	**Roof**	**Windows**	TOTAL FREQ.
Poor	1	0	0	2	1	0	0	5	9
Fair	1	1	0	0	2	1	0	1	6
Average	0	0	0	0	0	0	2	0	2
Good	0	0	1	0	0	0	2	2	5
Excellent	0	0	1	0	1	0	1	1	4

Source: Author (2017)

4.4 Simulation with Ecotect Analysis Software

There are some energy simulation programs and tools such as DOE2, Energy-10, Energy Plus and Ecotect Analysis Software. In this study Ecotect Analysis Software is used for the simulation. Ecotect is owned by Autodesk, Inc. “is a complete building design and environmental analysis tool that covers the full range of simulation and analysis functions required to the true understanding of how a building design will operate and do” (Schueter & Thessling, 2009). The analysis capabilities of the primary program include energy analysis, thermal analysis, and lighting/shading analyses. The case study building was model using Revit architecture 2011. Revit architecture groups the building components by categories, families, and types. A category is a group of elements that utilizes the model or documents a building design, and families are classes of elements in a category. A family classifies elements with a common set of parameters, identical use, and similar graphical representation. After modeling, the results from Revit must be exported to Autodesk Ecotect analysis software, one of the largest energy simulation tools under the Autodesk umbrella, for energy modeling. There are two types of imports to Ecotect, i.e., DXF and gbXML-based export from Revit architecture software. DXF is used primarily for geometry-based analysis, such as over-shadowing, ventilation modelling, daylight analysis, and external solar availability. The gbXML is based more upon space-based concerns, such as thermal performance, solar radiation, and energy demands. Based on the study and the type of analysis that is to be performed, gbXML-based export must be chosen to import the simulated file from Revit architecture to Ecotect analysis. Before implementing the export process, rooms known as zones must be produced to separate operational spaces of the building required for energy simulation in Ecotect. The other application of the room

element is to specify the area and volume of the spaces. Fig 4.5 shows the perspective of an export gbXML file, and the colors displayed in the model describe surface elements.

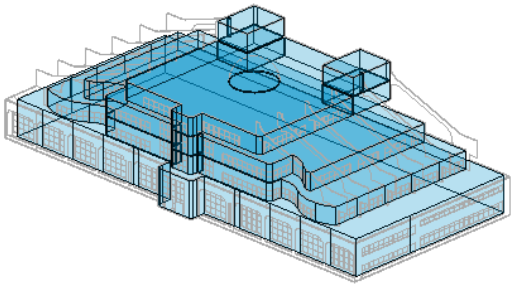


Figure 4.5: **Perspective of export gbXML of Ceddi Plaza, Abuja**

Source: Ecotect (2011)

4.5 Simulation Methodology

The case study building annual operational energy consumption was calculated through Ecotect Analysis. Since Nigeria is a tropical country, no heating load was considered in the calculation of annual operational energy consumption. After providing the drawing plans and materials specifications of the case study building in Revit Architecture 2011 software. The building is simulated using Autodesk Ecotect Analysis software; zones must be formed for creating various parts of the building. Without creating zones in Revit architecture, energy of the building's various spaces cannot be modelled. In fact, the file cannot be exported to Ecotect software. After creating zones, for exporting the simulation file from Revit to Ecotect, the gbXML based export way explained in the next parts must be used. This is the way that can export all building's specifications defined in Revit to Ecotect. By choosing gbXML based export, some basic and necessary assumptions for energy modelling such as location and types of the building must be established. After considering

essential assumptions, the file is exported to the Ecotect software for energy modelling and analysis as shown in Figure 4.6.

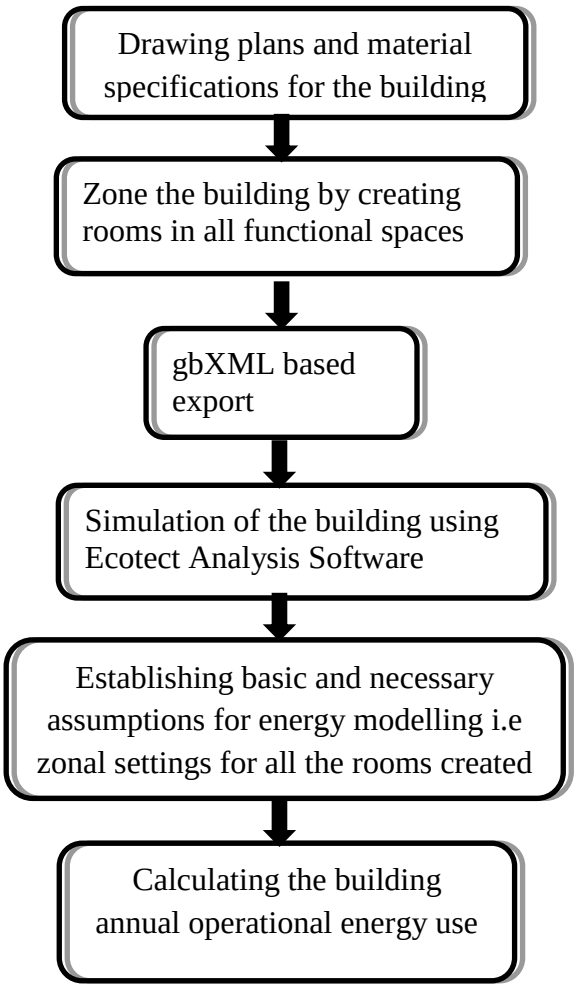


Figure 4.6 **Hierarchy of the Stimulation study**

Source: Author (2017)

In Ecotect, after establishing some additional assumptions, such as activity, type of system, and environmental temperature range for comfort of the building the baseline building annual operational energy use is calculated as shown in Table 4.7.

Table 4.7: **Basic assumption of zones for case study buildings**

BASIC ASSUMPTION OF THE ZONES IN THE ANALYSIS OF ENERGY CONSUMPTION FOR THE CASE STUDIES							
					THERMOSTAT RANGE		
FUNCTIONAL SPACE	**LIGHTING LEVEL**	**NUMBER OF PEOPLE**	**ACTIVITY**	**TYPE OF SYSTEM**	**LOWER BAND**	**UPPER BAND**	**HOURS OF OPERATION**
Shopping Area	900lux	5	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Hyper-market	900lux	70	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Cinema Hall	50lux	100	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-1:00AM
Basement	400lux	20	Walking 80w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Stair case	50lux	15	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Toilet	50lux	8	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Control Room	50lux	3	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Circulation Area	900lux	150	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Office	400lux	3	Reading 55w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Amusement / Games and Bowling Section	600lux	20	Exercise 1100w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Pantry / Food Court	300lux	35	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Event Hall	300lux	150	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM

Source: Author (2017)

4.6 Baseline design cooling energy consumption for case study 1 (Ceddi Plaza Abuja)

The baseline design of the case-study building involves concrete block render for the walls, double glaze aluminium frame for the windows, and concrete roof asphalt for the roof and concrete tiles on ground for the floors as shown on Table 4.9. By considering all months, it is seen that the energy used throughout the year to keep the building's temperature between 18^0C and 22^0C based on these materials was 192.497kwh per square metre. There is just a cooling load for all months of a year due to the location of the building in Abuja Nigeria, which is a very hot and humid area. The highest amount of energy consumption occurs on. 7 March as shown in Table 4.8a and 4.8b. Conduction is a factor that may have a large impact on the loading values for the building. A breakdown of the passive gains was acquired from Ecotect as a visual sign of the contribution of each part of the building in load losses and gains as shown on Table 4.10. It is clearly evident that conduction has the largest impact on load losses as shown in Figure. 4.7 below. It might be possible to reduce this to some extent by changing the materials with low thermal mass.

Table 4.8 a: **Monthly heating and cooling loads of case study 1**

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 0.0 C - No Heating.
Max Cooling: 637128 W at 13:00 on 17th March

MONTH	HEATING (kWh)	COOLING (kWh)	TOTAL (kWh)
Jan	0	127574.258	127574.258
Feb	0	136152.703	136152.703

Table 4.8 b: **Monthly heating and cooling loads of case study 1**

	HEATING	COOLING	TOTAL
MONTH	**(kWh)**	**(kWh)**	**(kWh)**
Mar	0	161372.297	161372.297
Apr	0	139615.234	139615.234
May	0	129342.023	129342.023
Jun	0	108567.242	108567.242
Jul	0	102736.891	102736.891
Aug	0	102626.547	102626.547
Sep	0	95019.32	95019.32
Oct	0	117258.016	117258.016
Nov	0	112941.531	112941.531
Dec	0	117468.766	117468.766
TOTAL	**0**	**1450674.875**	**1450674.875**
PER M²	**0**	**192.497**	**192.497**
Floor Area:	**7536.083 m2**		

Source: Ecotect (2011)

Table 4.9: **Types of materials used for each building component (Case Study 1)**

Building Component	Type of Materials
Walls	Hollow Block Render
Windows	Double Glaze Aluminium Frame
Roof	Concrete Roof Asphalt
Floors	Concrete Tile on Ground

Source: Author (2017)

Table 4.10: **Passive gains breakdown for case study 1**

GAINS BREAKDOWN - All Visible Thermal Zones

FROM: 1st January to 31st December

CATEGORY	LOSSES	GAINS
FABRIC	1.20%	18.50%
SOL-AIR	0.00%	10.20%
SOLAR	0.00%	19.60%
VENTILATION	0.00%	27.60%
INTERNAL	0.00%	19.50%
INTER-ZONAL	98.80%	4.60%

Source: Ecotect (2011)

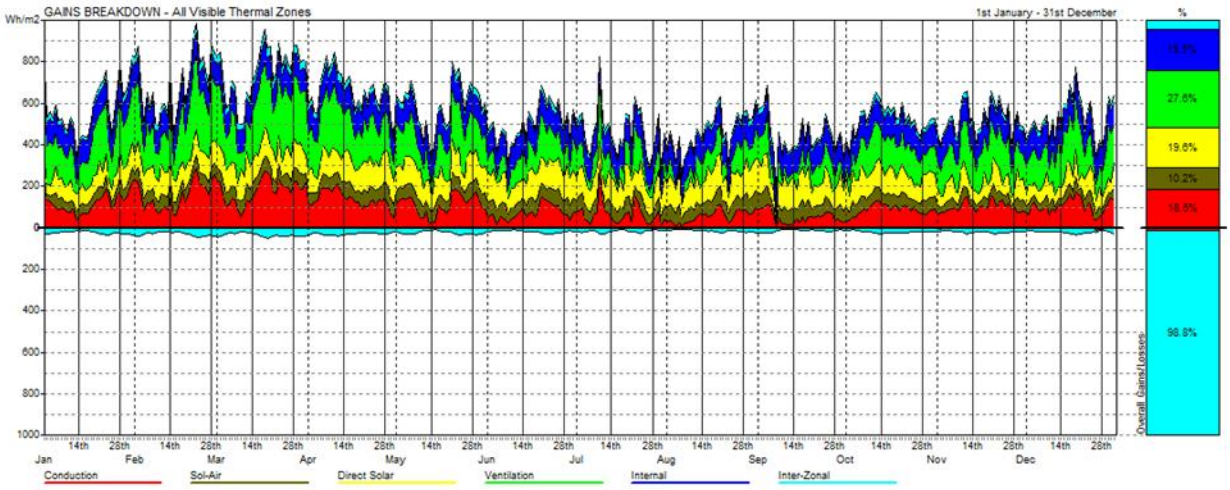


Figure 4.7: **Breakdown of passive gains (case study 1)**

Source: Ecotect (2011)

4.6.1 Energy modelling of case study 1

After entering to Ecotect, it could be seen that it has the ability to identify those elements simulated in Revit. It shows that these software products can be integrated to facilitate simulation and analysis. Before starting the analysis, we can evaluate the building's shadow on various days of the year and also various times of a specified day. First, weather specification of the building must be loaded based on its location, since different locations have different sun paths and conclusively dissimilar shadow positions. After considering the weather location of Abuja Nigeria, the daily and annual sun path can be visualized. This just allows the visual interpretation of exactly where the sun is and its impacts on the various parts of the building during different times of the day. It can also be helpful in visualizing the building's shadow throughout an entire day. Figs. 4.8, 4.9 and 4.10 below illustrate the sun's daily and annual path on the building and the spherical projection of the sun's position.

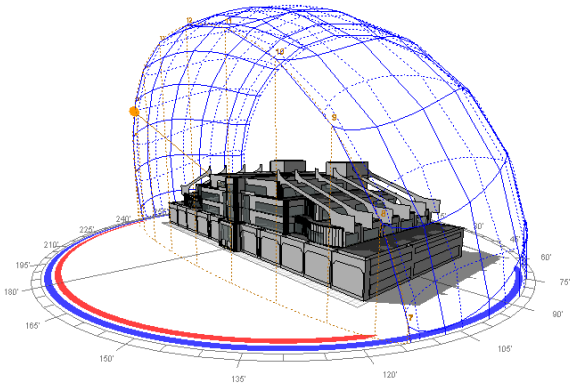


Figure 4.8 **Daily and annual visualizations of the sun's path of Ceddi Plaza, Abuja**

Source: Ecotect (2011)

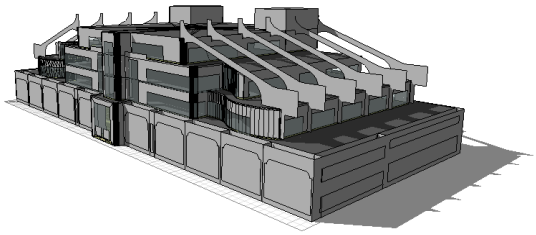


Figure 4.9: **Perspective and 3D views of simulated building of Ceddi Plaza, Abuja**

Source: Ecotect (2011)

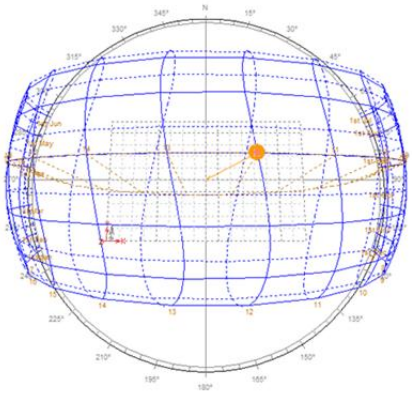


Figure 4.10: **Spherical projection of the sun's position of Ceddi Plaza, Abuja**

Source: Ecotect (2011)

4.6.2 Analysis of solar energy absorption of case study 1

Ecotect software can calculate how much solar energy will be absorbed by the surfaces of the building, and this can be helpful, especially when photovoltaic (PV) systems are used in the building in the form of solar panels to convert sunlight into electricity. After the calculations, the shape of the building is turned into a range of colours from yellow to blue, indicating the greatest and least solar energy absorption by the surfaces of the building as

shown in Figure 4.11 below. Choosing the orientation is one of the effective issues that should be considered for enhancing solar energy absorption, and it is usually chosen during the preliminary design stage. The best choice of orientation in terms of solar energy absorption can lead to optimum solar energy absorption for the building. The best and worst orientation for the absorption of solar energy can be calculated through the Ecotect analysis software. However, this optimization may not be applicable due to various limitations, such as adjacent building position and the environmental situation.

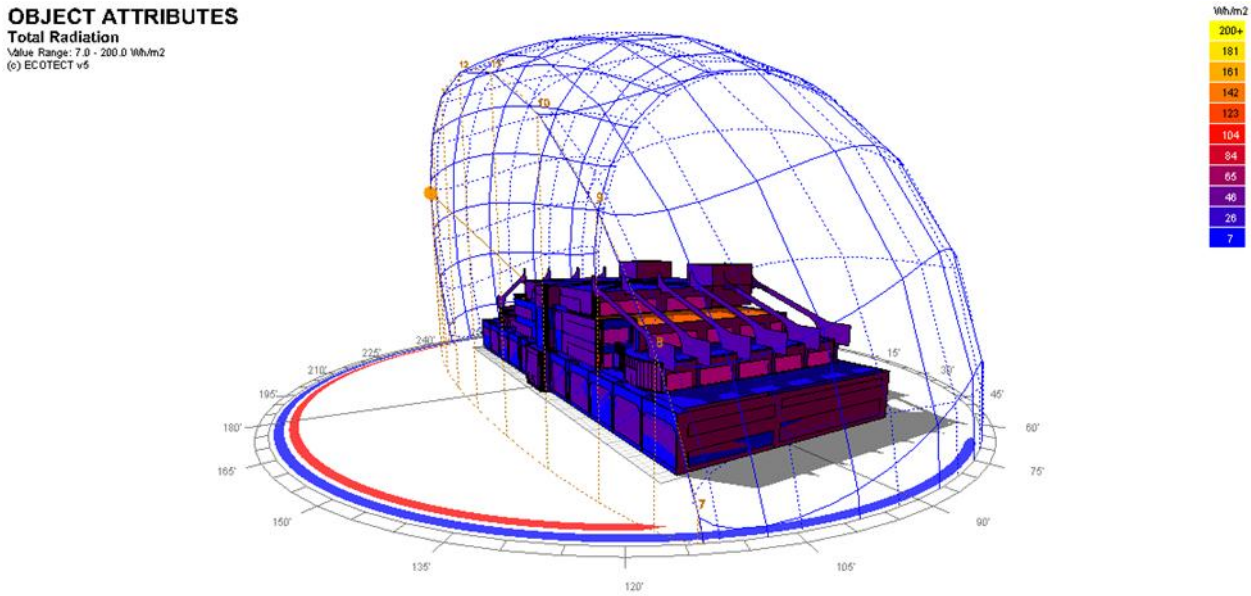


Figure 4.11: **Solar energy absorption by surfaces of the building orientation of Ceddi Plaza, Abuja**

Source: Ecotect (2011)

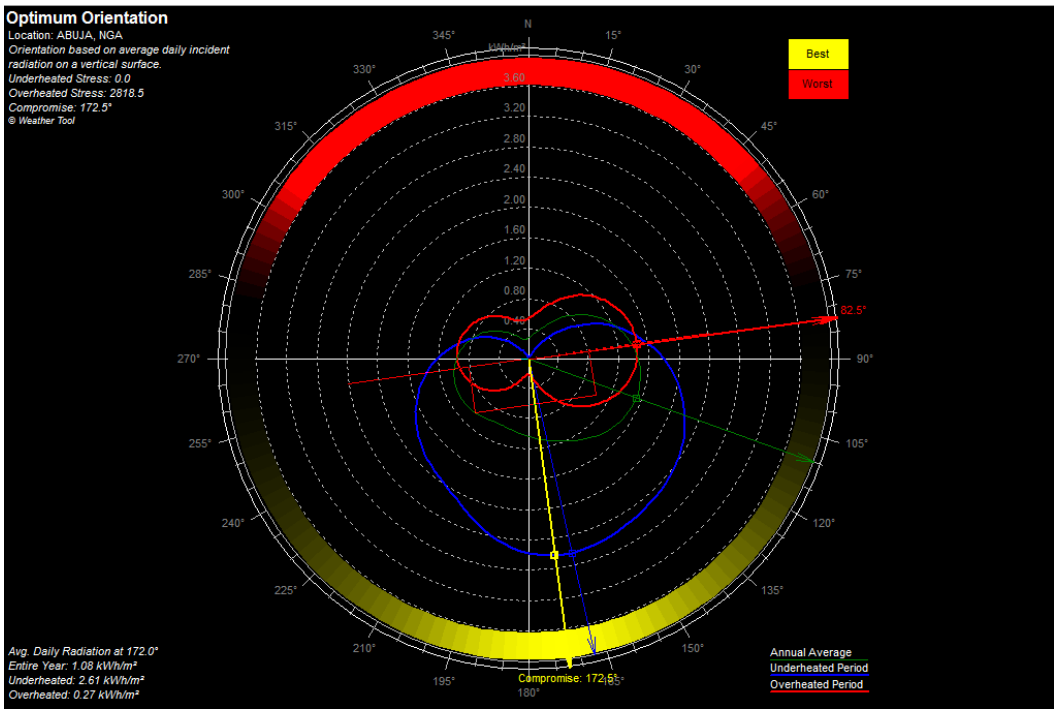


Figure 4.12: **Calculation of the best and worst orientation.**

Source: Ecotect (2011)

Fig. 4.11 above shows the degree of solar energy absorption by surfaces of the building in the specified orientation and position, and the best and worst orientations of the buildings for solar energy absorption are shown in yellow and red lines, respectively. As shown in Fig.4.12 above, the best and worst orientations were 172.5^0 and 82.5^0 from the north respectively.

4.7 Baseline design cooling energy consumption for case study 2 (Silverbird Entertainment Centre Abuja)

The baseline design of the case-study building involves concrete block render for the walls, double glaze aluminium frame for the windows, and corrugated aluminium roof for the roof and concrete tiles suspended for the floors as shown in Table 4.12. By considering all months, it is seen that the energy used throughout the year to keep the building's

temperature between 18^0C and 22^0C based on these materials was 164.134kwh per square metre. There is just a cooling load for all months of a year due to the location of the building in Abuja Nigeria, which is a very hot and humid area. The highest amount of energy consumption occurs on 21st February as shown on Table 4.11. Conduction is a factor that may have a significant impact on the loading values for the building. A breakdown of the passive gains was acquired from Ecotect as a visual sign of the contribution of each part of the building in load losses and gains. It is clearly evident that ventilation and conduction has the largest impact on load losses as shown in Figure 4.13.

Table 4.11: **Monthly heating and cooling loads of case study 2**

Monthly Heating/Cooling Loads

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 0.0 C - No Heating.
Max Cooling: 2024370 W at 13:00 on 21st February

MONTH	HEATING (kWh)	COOLING (kWh)	TOTAL (kWh)
Jan	0	426001.219	426001.219
Feb	0	452451.656	452451.656
Mar	0	536288.188	536288.188
Apr	0	461655.531	461655.531
May	0	425635.656	425635.656
Jun	0	352604	352604
Jul	0	334173.188	334173.188
Aug	0	330767.219	330767.219
Sep	0	306816.469	306816.469
Oct	0	385199.375	385199.375
Nov	0	378815.531	378815.531
Dec	0	392789.969	392789.969
TOTAL	**0**	**4783198**	**4783198**
PER M²	**0**	**164.134**	**164.134**
Floor Area:	**29141.971 m2**		

Source: Ecotect (2011)

Table 4.12: **Types of materials used for each building component (Case Study 2)**

Building Component	Type of Materials
Walls	Hollow Block Render
Windows	Double Glaze Aluminium Frame
Roof	Corrugated aluminium Roof
Floors	Concrete Tile Suspended

Source: Author (2017)

Table 4.13: **Passive gains breakdown case study 2**

GAINS BREAKDOWN - All Visible Thermal Zones

FROM: 1st January to 31st December

CATEGORY	LOSSES	GAINS
FABRIC	0.50%	18.60%
SOL-AIR	0.00%	14.90%
SOLAR	0.00%	7.20%
VENTILATION	0.00%	27.90%
INTERNAL	0.00%	17.20%
INTER-ZONAL	99.50%	14.20%

Source: Ecotect (2011)

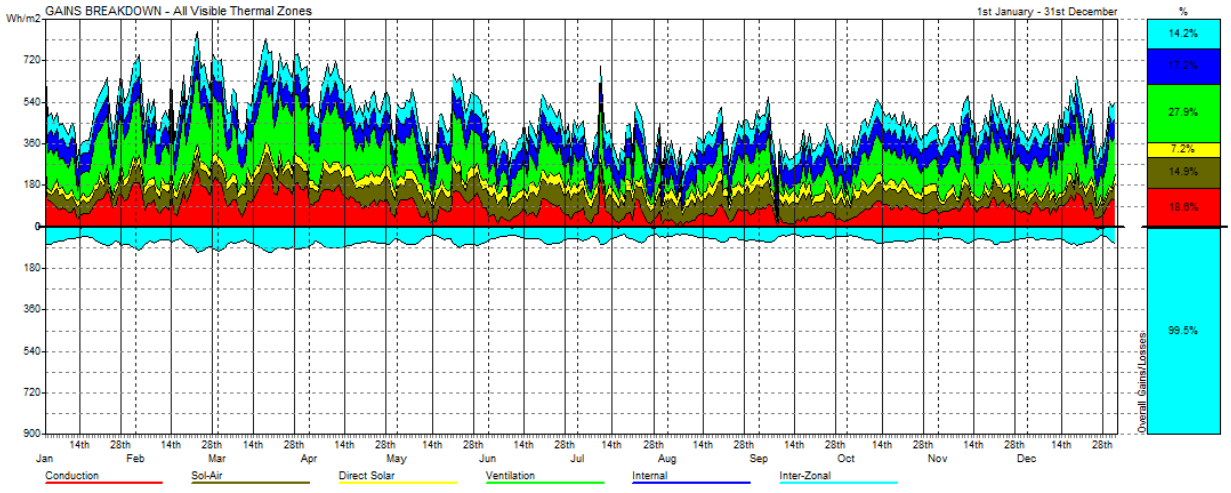


Figure 4.13: **Passive Gains Breakdown Graph (case study 2)**

Source: Ecotect (2011)

4.7.1 Energy Modeling of case study 2

After entering to Ecotect, it could be seen that it has the ability to identify those elements simulated in Revit. It shows that these software products can be integrated to facilitate simulation and analysis. Before starting the analysis, we can evaluate the building's shadow on various days of the year and also various times of a specified day. First, weather specification of the building must be loaded based on its location, since different locations have different sun paths and conclusively dissimilar shadow positions. After considering the weather location of Abuja Nigeria, the daily and annual sun path can be visualized. This just allows the visual interpretation of exactly where the sun is and its impacts on the various parts of the building during different times of the day. It can also be helpful in visualizing the building's shadow throughout an entire day. Figs. 4.14 and 4.15 below illustrate the sun's daily and annual path on the building and the Perspective view of the simulated building.

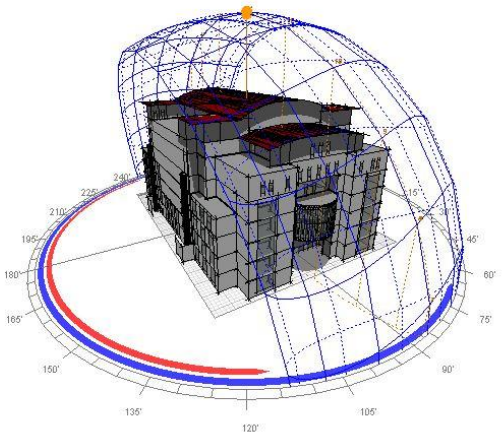


Figure 4.14: **Daily and annual visualizations of the sun's path of Silverbird Abuja**

Source: Ecotect (2011)

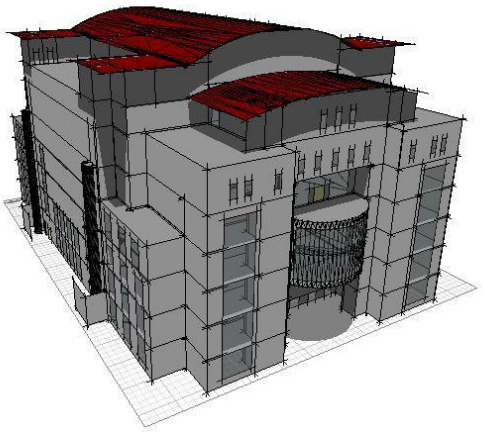


Figure 4.15: **Perspective and 3D views of simulated building of Silverbird Abuja**

Source: Ecotect (2011)

4.7.2 Analysis of solar energy absorption of case study 2

Ecotect software can calculate how much solar energy will be absorbed by the surfaces of the building, and this can be helpful, especially when photovoltaic (PV) systems are used in the building to convert sunlight into electricity. After the calculations, the shape of the building is turned into a range of colours from yellow to blue, indicating the greatest and least solar energy absorption by the surfaces of the building as shown in Figure 4.16.

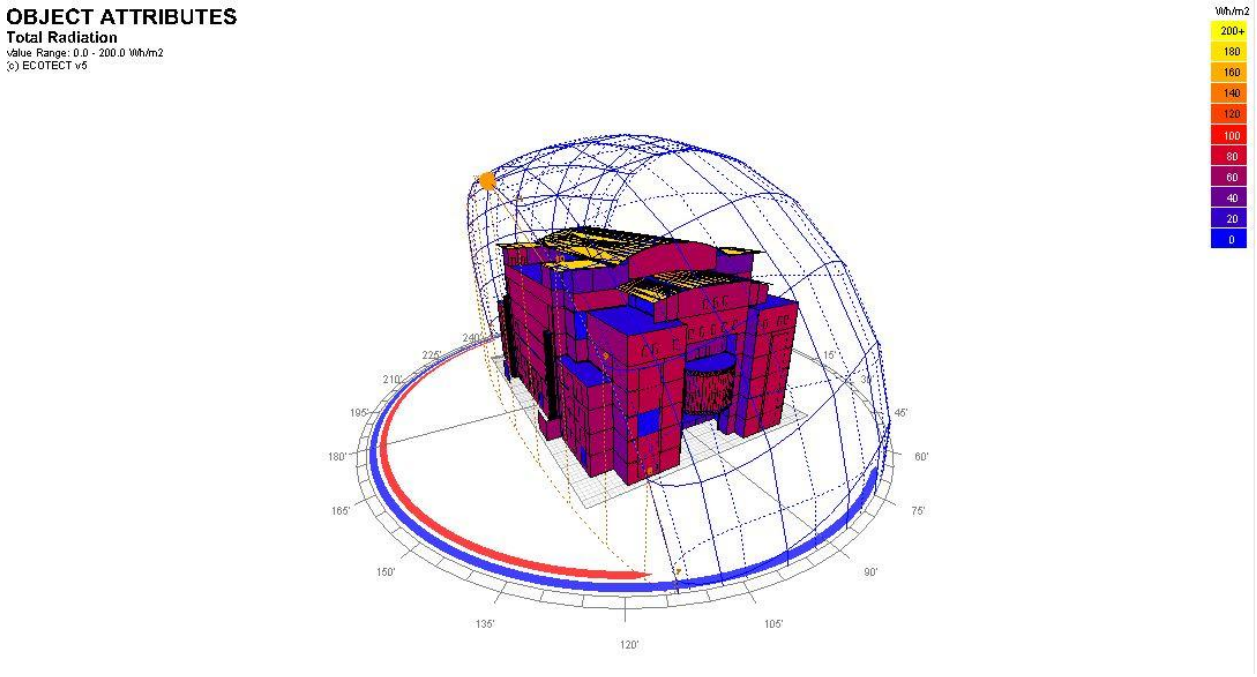


Figure 4.16: **Solar energy absorption by surfaces of the building orientation of Silverbird Abuja**

Source: Ecotect (2011)

4.8 Annual Energy Consumption Validation

In order to validate the results obtained from the Ecotect analysis software, an energy consumption survey was conducted for the case study 2 building and a random sample of a

shop within the central business district of Abuja, as shown in Table 4.14, Figure 4.17 and Table 4.15.

Table 4.14: **Annual Energy Consumption Validation Table**

Energy Consumption Table Of Silverbird Entertainment Centre Abuja				
Appliances	**Power (kw)**	**Quantity**	**Hours of Operation**	**Annual Energy Consumption (kwh)**
Mechanical Machines				
Central Plant Air Conditioning System	0.53 kw per ton (350 tons) 1ton=3.5kw 649.25kw	1	18	4,265,572.5
Escalator	7.5 H.P=5.592KW	10	14	285,751
Elevator (Panoramic)	2943w=2.943kw	2	14	30,077.46
Elevator (Hoist)	3924w=3.924kw	1	7	10,025.82
Pro Cinema 1080p 3LCD Projector	528W=0.528kw	12	16	37,002.24
Lighting				
Compact Fluorescent	18w=0.018kw	150	18	17,739
Incandescent Lamp	15w=0.015kw	800	18	78,840
Incandescent Lamp	20w=0.020kw	400	18	52,560
Halogen Lamp	300w=0.300kw	10	12	13,140
Kitchen Equipment				
Coffee Maker	1000w=1kw	2	2	1,460
Dish Washer	1500W=1.5kw	5	2	5,475
Micro wave oven	1500kw=1.5kw	7	2	7,665
Toaster oven	1000w=1kw	7	2	5,110
Freezer	1000w=1kw	12	24	105,120
Refrigerator	800w=0.8kw	30	24	210,240
Electronics				
Desktop pc	75w=0.075kw	90	14	34,492
Television	150w=0.150kw	20	14	15,330
Stereo System	33w=0.033kw	5	10	602.25
TOTAL				**5,176,202.27**
TOTAL FLOOR AREA	**29,141.971 m^2**			
PER M^2				**177.620**
Note: For Elevator Power=work/time: Work=Force*Distance: Force=mass*acceleration Power=mass*acceleration*distance/time. 1 horse power (h.p) =0.7457kw				

Source: Author (2017)

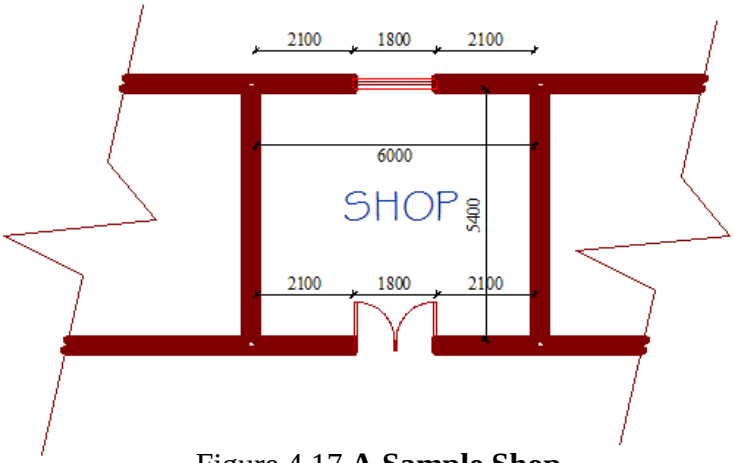


Figure 4.17 **A Sample Shop**

Source: Author (2017)

Table 4.15: **Annual energy consumption of the sample shop**

ENERGY CONSUMPTION OF A SHOP WITHIN THE CENTRAL BUSINESS DISTRICT, ABUJA				
Appliances	**Power (kw)**	**Quantity**	**Hours of Operation**	**Annual Energy Consumption (kwh)**
Split A.C	1500W=1.5KW	2	8	7,488
Television	150w=0.150kw	1	8	374.2
Incandescent Bulbs	40w=0.040kw	6	8	599.04
Fridge	1000w=1kw	1	8	2,496
TOTAL				**10,957.24**
TOTAL FLOOR AREA		32.4 m^2		
PER M^2				**338.186**

Source: Author (2017)

4.9 Summary of Findings

Building simulation and investigating the performance of the building virtually in the pre-construction and/or even during the construction stage will help decision makers, such as architects and engineers to select specifications with the least detrimental impact to the environment.

After the essential data required for the simulation had been gathered and importing the data to the energy analysis software, the two case study buildings was simulated using the Ecotect analysis, and the annual energy consumption of the building was estimated. The annual amount of energy used for the case study 1 and 2 buildings was determined to be **1,450,674.875kwh** and **4,783,198kwh** respectively, and the energy consumption per square meter is **192.497kwh** and **164.134kwh** respectively. This result indicate the case study 2 (Silverbird entertainment centre Abuja) has applied more passive principles than case study 1 (Ceddi plaza Abuja) as shown in Table 4.16, Figures 4.18, 4.19 and 4.20. The earlier checklist analysis also reflects the same.

Table 4.16: **Annual Operational Energy Consumption of Case Study 1 & 2**

	Ceddi Plaza Case Study 1	Silverbird Case Study2
MONTH	**Cooling (kWh)**	**Cooling (kWh)**
Jan	127574.3	426001.2
Feb	136152.7	452451.7
Mar	161372.3	536288.2
Apr	139615.2	461655.5
May	129342	425635.7
Jun	108567.2	352604
Jul	102736.9	334173.2
Aug	102626.5	330767.2
Sep	95019.32	306816.5
Oct	117258	385199.4
Nov	112941.5	378815.5
Dec	117468.8	392790
TOTAL	**1450675**	**4783198**
PER M²	**192.497**	**164.134**
Floor Area:	**7536.083 m2**	**29141.971 m2**

Source: Author (2017)

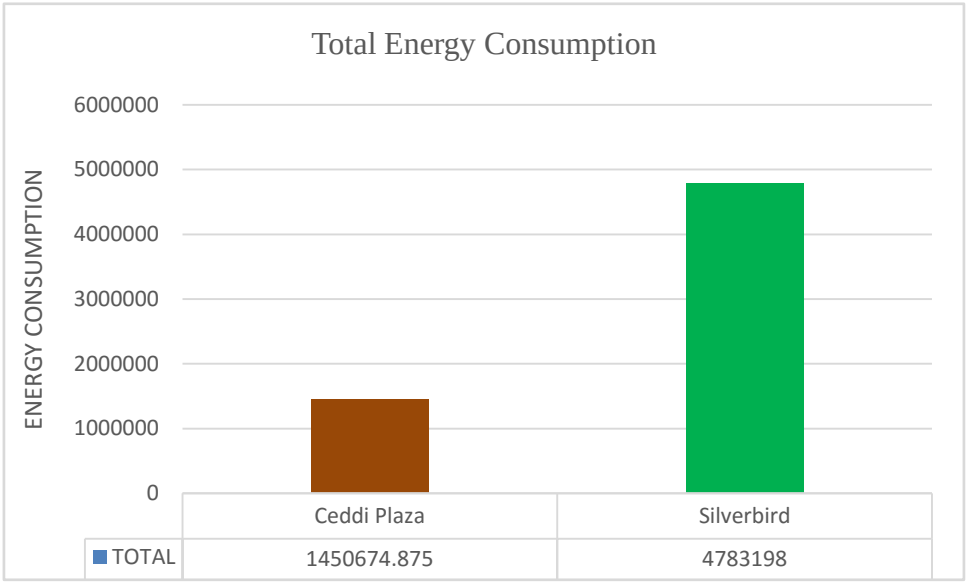


Figure 4.18: **Total energy consumption of case study 1 and 2**

Source: Author (2017)

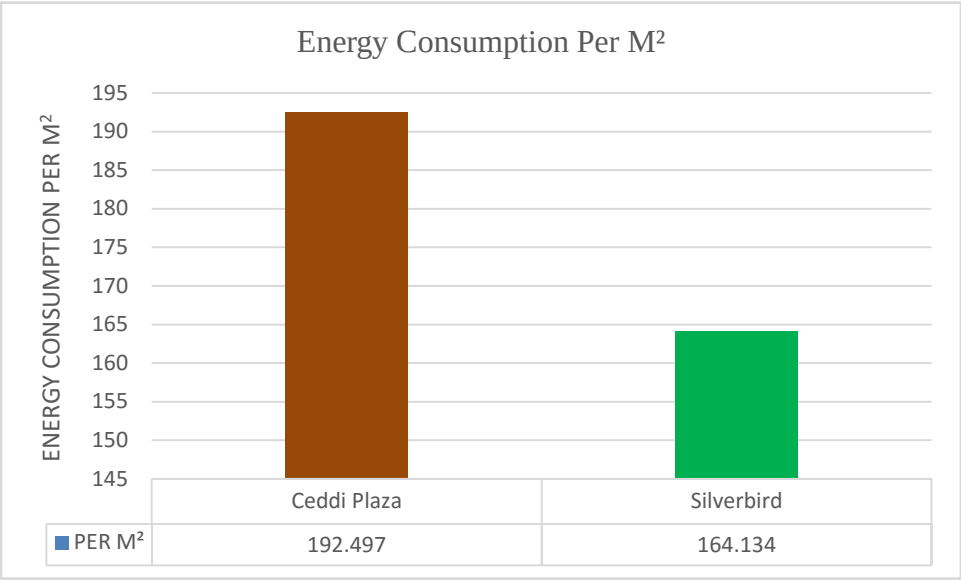


Figure 4.19: **Energy consumption per M^2 of case study 1 and 2**

Source: Author

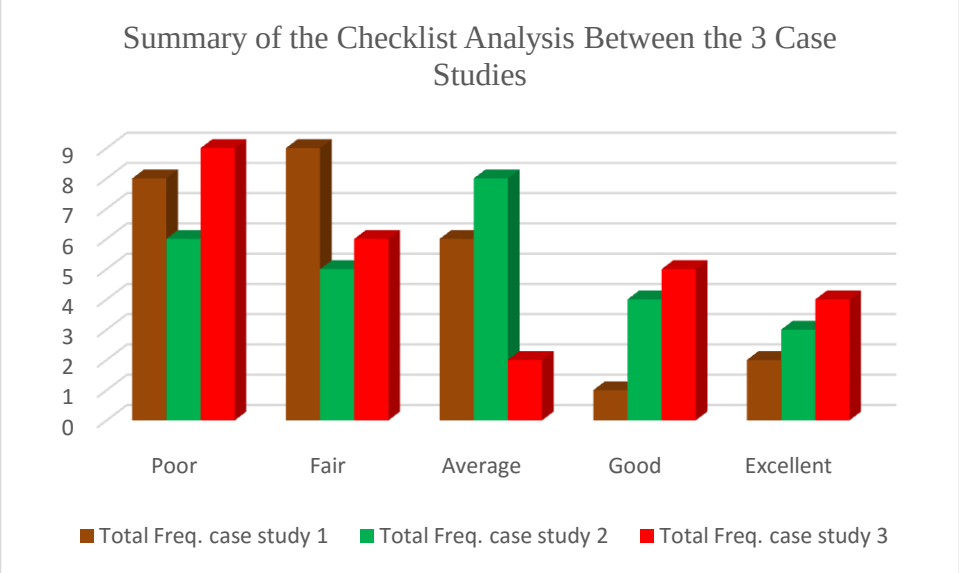


Figure 4.20: **summary of the checklist analysis between the 3 case studies**

Source: Author

CHAPTER FIVE

DESIGN CRITERIA

5.0 The Site

5.1 Site: Abuja, Nigeria

Basic information:

Latitude:	+9.06 (9°03'36"N)
Longitude:	+7.49 (7°29'24"E)
Time zone:	GMT+1hours
Country:	Nigeria
Continent:	Africa
Sub-region:	Western Africa
Altitude:	~520 m

5.2 Site Location

Following the agreement reached between **Topwide Ventures Limited** and **Artee group**, the operators of spar supermarket the proposed shopping mall will be located at Life camp area of the federal capital territory, Abuja as shown on Figs. 5.1, 5.2, 5.3 below. These will attract shoppers from Gwarinpa, Jabi, life camp, Mabushi, Utako and other part of the Federal Capital Territory (F.C.T). Plates XX, XXI, XXII, XXIII, XXIV shows south, west, north, north-east, north-west views of the proposed site.



Figure 5.1: **Map of Nigeria with situation of Abuja**

Source: (nigeriazipcodes, 2016)

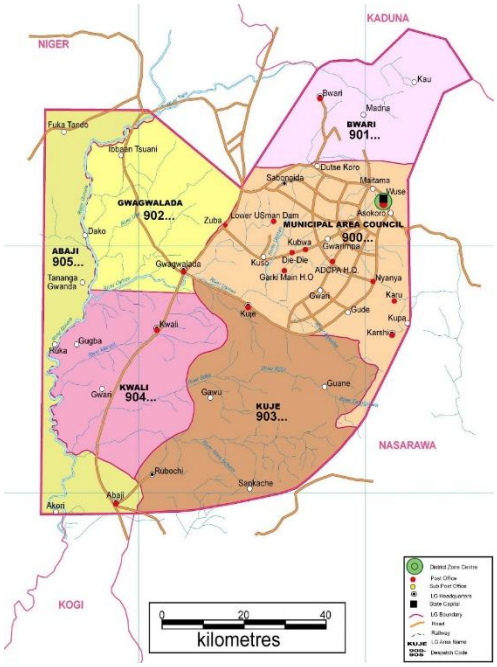


Figure 5.2: **Map of Abuja the Federal Capital Territory**

Source: (nigeriazipcodes, 2016)

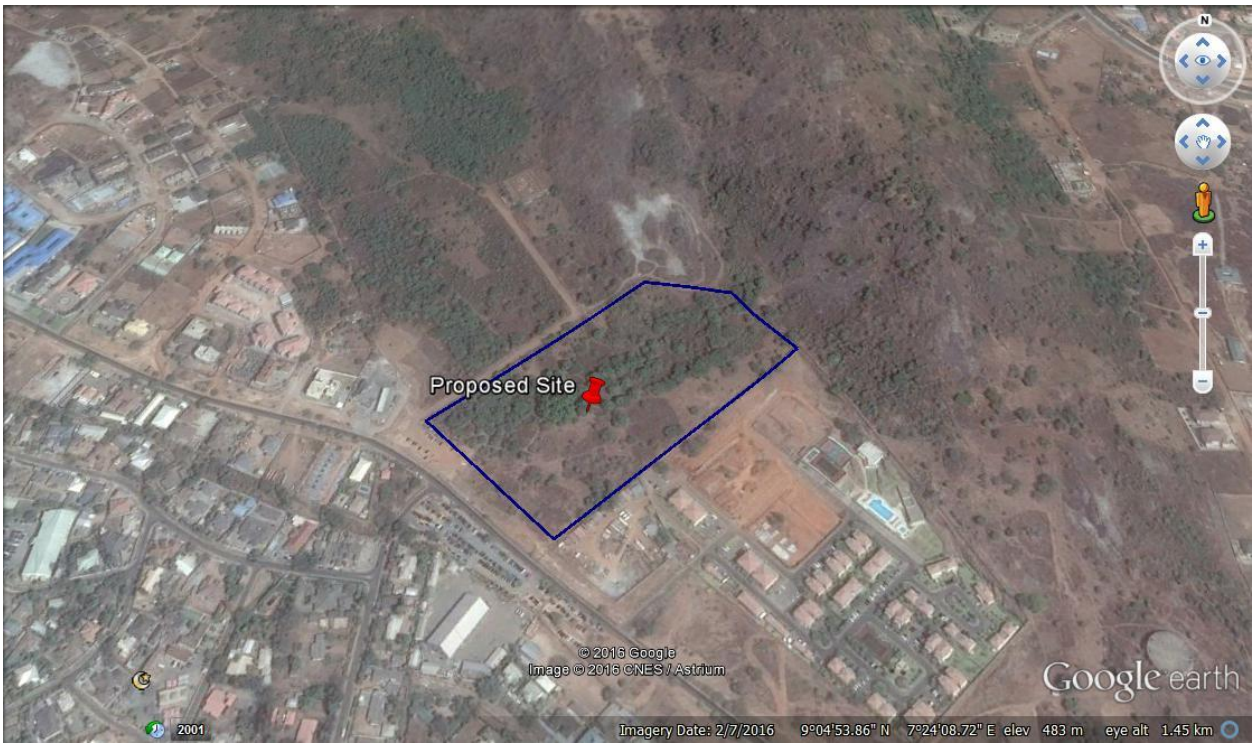


Figure 5.3 : **Proposed site location map**

Source: Google map image



Plate XX: **South view of site**

Source: Field Survey (2016)



Plate XXI: **West view of site**

Source: Field Survey (2016)



Plate XXII: **North view of site**

Source: Field Survey (2016)



Plate XXIII: **North East view of site**

Source: Field Survey (2016)



Plate XXIV: **North West view of site**

Source: Field Survey (2016)

5.3 Abuja Climate

Abuja has two distinct seasons, namely the rainy season that begins around March and runs through October and the dry season which begins from October and ends in March. However, within these seasons is a brief harmattan season that is occasioned by the north east trade wind and the attendant dust haze, increased cold and dryness.

- **Temperature**

Temperatures rise as high as 18‟ in the dry season being recorded and lowest in rainy season in the months of august as shown in Fig. 5.4.

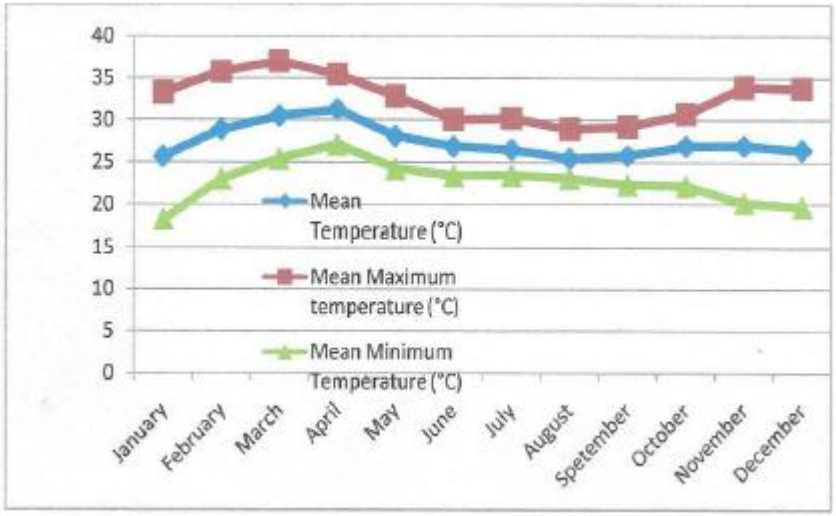


Figure 5.4: **Temperature chart**

Source: (gaisma, 2016)

- **Humidity**

Humidity levels rise high during rainy season and are low during the dry season between months of November to march as shown on Fig. 5.5.

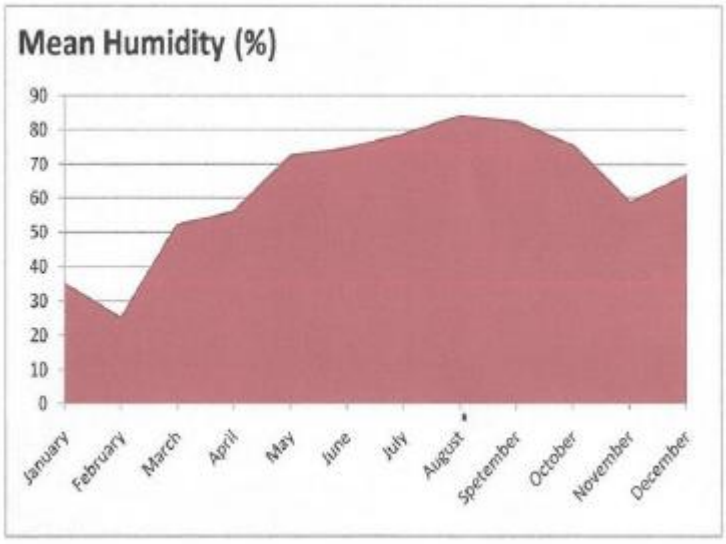


Figure 5.5: **Humidity chart**

Source: (gaisma, 2016)

- **Rainfall**

Rainy months fall in-between April and October with an average duration of 185 days as shown on Fig 5.6.

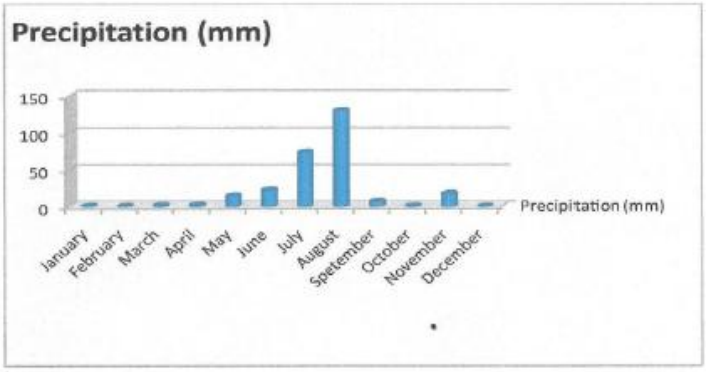


Figure 5.6: **Precipitation chart**

Source: (gaisma, 2016)

- **Wind speed**

Tropical maritime and tropical continental air masses are the two dominant masses domineering the Abuja air mass. The tropical continental air mass comes with the dry season and is developed over the Sahara desert and the tropical maritime air mass the wet season and is therefore warm and moist as shown on Fig. 5.7.

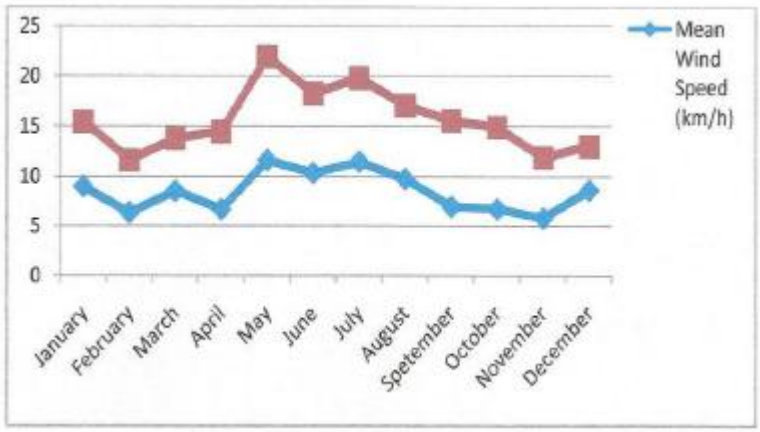


Figure 5.7: Wind speed chart

Source: (gaisma, 2016)

- **Sun path diagram:**

Sunshine ranges from a minimum of 130 hours in the Niger Delta to over 3200 hours in the extreme north-east of the country as shown on Fig 5.8.

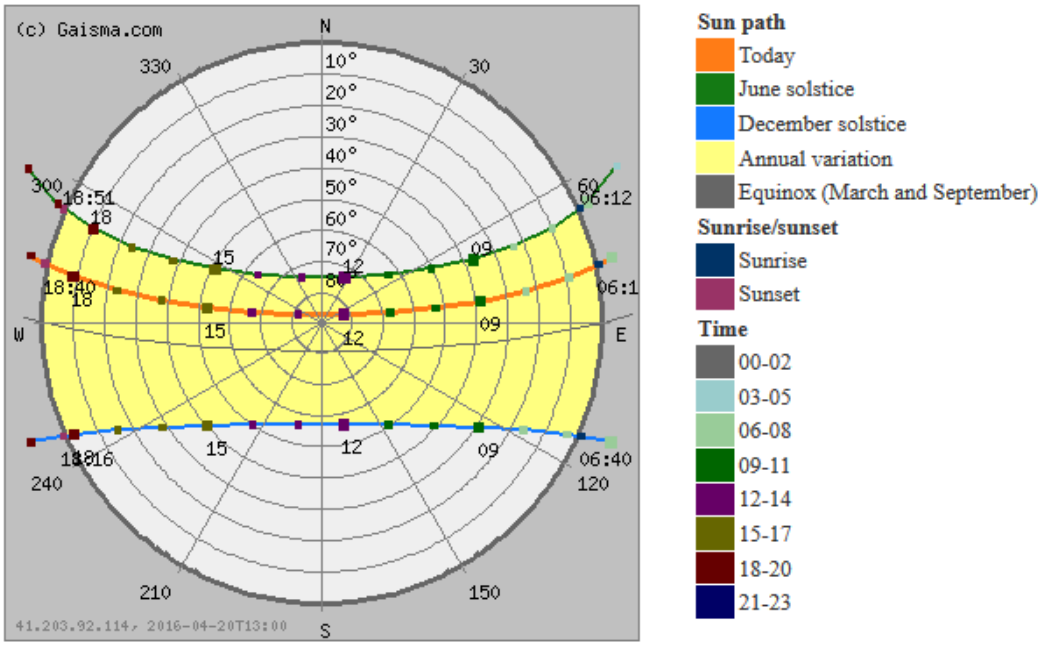


Figure 5.8: **Sun path diagram**

Source: (gaisma, 2016)

5.4 Design Considerations

5.4.1 Design Checklist

Provide amenity through provision of:

- Quality facilities, materials and design excellence
- Vitality, colour and interest
- Personable spaces, scale and comfort
- Comfortable street furniture and other facilities
- Landscape that relates well to the built environment and is accessible
- Legibility and ease for people to find their way around
- Easily identifiable facilities

- Design that facilitates effective maintenance of spaces and facilities
- Safe spaces and facilities
- A landscape design that is flexible to cater for changes in commercial and community uses.

5.4.2 Goods deliveries and emergency access

Provision for back-of-house goods deliveries to the various premises needs to be addressed.

Loading zones need to be identified and appropriate areas marked and sign posted. These sites should be free of obstruction and have adequate entry points for movement of delivery and service vehicles.

Provide a clear and unobstructed access for emergency service vehicles as determined by the building structure.

5.4.3 Traffic and parking

In the refurbishment of a public area consideration often needs to be given to traffic flow, car parking, roads and bus stop parking, and their relationship to pathways, lighting, disability access, planting and shelter requirements to ensure adequate vehicle and pedestrian circulation.

5.4.4 Pedestrian movement

Pedestrian movement needs to be studied and a hierarchy of entry points or ‘doorways’ established to provide defined ease of access plus an identifiable character for the centre. Attention should be given to logical and well laid out integration and connection with the adjacent spaces and a continuous path of travel. For safety reasons avoid hidden doorways or alley type access points to collect people from the surrounding car parks.

5.4.5 Street furniture

Street furniture should be chosen to suit its function, comfort requirements and users. Materials and designs that are easy to clean and maintain, resist vandalism and discourage damage by skateboards are other considerations. Street furniture should not encroach upon the continuous accessible path of travel.

5.4.6 Signage

The aim of signage design for shopping malls is to improve name recognition and direction. It is necessary to provide materials that are easy to clean and maintain and resist vandalism. Tactile signs are preferred for people who have disabilities.

5.4.7 Public toilets

Public toilet facilities in shopping malls need to be analysed in terms of their adequacy in lighting, disabled person access, suitability of location, safety and security factors.

5.5 Circulation in Shopping Malls

Shopping malls attract huge throngs of people. They need to move freely both horizontally and vertically within and without the mall. This is necessary so as to enhance comfort and a feel of safety as one is going about their business inside the shopping mall. It also help the users to understand the architecture as they move through a building and its spaces (Yasimin, 2010).

5.6 Types of Circulation

5.6.1 Horizontal Circulation

Horizontal circulation in a building may comprise access routes through open-plan areas, walkways, corridors and lobbies as shown on Plate XXV and Table 5.1. The overall

arrangement of access routes should be logical, understandable, useable, and as direct as possible in terms of providing access to key facilities (Centre for Excellence in Universal Design, 2013).

Checklist – Horizontal circulation

- Plan overall layout to be as logical and direct as possible.
- Avoid changes of level within a storey.
- Maintain access routes carefully and keep them clear of potential obstructions.
- Ensure access routes through open-plan areas are well defined.
- Incorporate handrails to both sides of walkways and provide seating at regular intervals (Centre for Excellence in Universal Design, 2013).



Plate XXV: **Horizontal Circulation**

Source: (Centre for Excellence in Universal Design, 2013)

5.6.2 Vertical Circulation

The provision of a passenger lift and escalators to all floors in a building will provide the most convenient and safe means of access and egress for building users. Passenger lifts and the escalators should be sufficiently large, have adequate circulation space on landings and controls that are easy to use as shown on Plate XXVI (Centre for Excellence in Universal Design, 2013).

Checklist – Vertical circulation

- Avoid changes of level within a storey for new buildings.
- Design and maintain stairs to provide safe access at all times even if rarely used.
- Install passenger lifts and escalators in preference to other devices, as they provide the most convenient means of vertical circulation.
- Consider improving controls, signalling, safety and communication devices, and surface finishes in existing lifts (Centre for Excellence in Universal Design, 2013).





Plate XXVI: **Vertical Circulation**

Source: (Centre for Excellence in Universal Design, 2013)

Table 5.1: **Circulation Design Requirement**

CIRCULATION DESIGN REQUIREMENT		
S/N	**Design Element**	**Requirement**
1	**Circulation**	More Elevators, Escalators, Stairs
		Smooth Ramp
		Wide pedestrian walks, lobbies and corridors
		Adequate clear space for circulation
2	**Entering and Exiting**	Ease to access the entrance / Exits
		Close to car park
3	**Way finding**	Understandable sign
		Ease of navigation
		Simple layout
4	**Obtaining products/services**	More and comfortable waiting areas
		Wide passages in shops
		Ease of reach to all products
5	**Public Amenities**	Disable Toilets
		Audio-visual features in ATMs
		Ease of reach to public telephones

Source: (Yasimin, 2010)

CHAPTER SIX

DESIGN REPORT

6.0 Preliminary Proposal

The aim of this research is to reduce the annual operational energy demand of a shopping mall in Abuja the Federal Capital Territory (FCT) of Nigeria, through passive approach that will be peculiar to our local climate here. The high internal temperature in the hot season and the low in the cold season in Nigeria are not only working against an effective use of energy, but generate thermal shocks at the entrances of our buildings instead of providing opportunity for the human body to adapt or rather drive the user towards an adaptive comfort. The design will employ all the necessary core principle of passive design that will fit a shopping mall in our local climate. These can be achieve through effective planning and zoning of those core component of shopping mall design i.e. for conceptual stage to design stage and up to it operational stage.

The design is such that the users enjoys all the passible facilities that will help them refresh, entertain, shop and relax after a hard day's work, these will be achieve through effective circulation within and around the mall. The mall will take into consideration all categories of users and should be devoid of gender, religion or disability. The design brief incorporate the current trends of shopping mall design equipped with the necessary state of the art facilities.

6.1 Design Concept

The design concept is based on passiveness which is an approach that takes advantage of climate to maintain a comfortable temperature range within and around a building, and this passiveness is rooted in some principles of sustainable design as shown on Figs. 6.1,6.3, 6.4,6.5,6.6, while Fig 6.2 shows the passive design frame work employed in the shopping mall design.

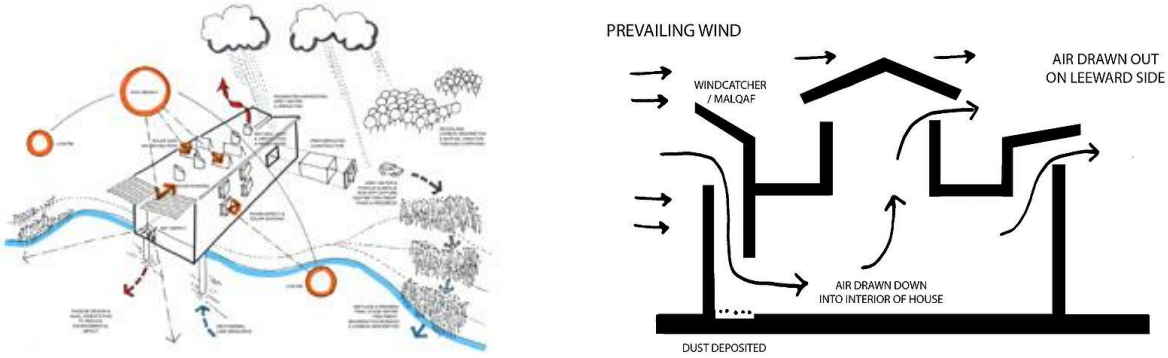


Figure 6.1 **passive design approach**

Source: Passive Design (2016)

6.2 Passive design frame work for shopping mall

PASSIVE DESIGN FRAME WORK FOR SHOPPING MALL			
Avoid heat gain	**Encourage natural ventilation**	**Make use of natural light**	**Create cool outdoor areas**
Orient the building to reduce exposure to midday sun, particularly summer sun. **Use double glazing on windows that cannot be effectively shaded** **Use insulation, light colours.**	**Include open-able windows and courtyards that enable the building to naturally ventilate and also to prevent stack effect.**	**Introduce courtyards and large double glazed windows to optimized natural lighting.** **To align the shops along the leeward side of the building.**	**Use landscaping to provide shade without blocking cooling breezes and use planting to reduce ground temperature and minimize reflected heat.**

Figure 6.2: **passive design frame work for shopping mall**

Source: Author (2017)

- **How to avoid heat gain**

Sustainable building components

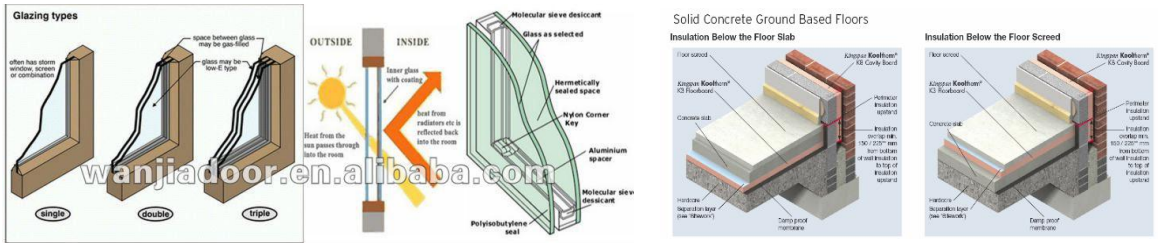


Figure 6.3: **Avoid heat gain into the building envelope**

Source: Passive Design (2016)

- **Encourage natural ventilation**

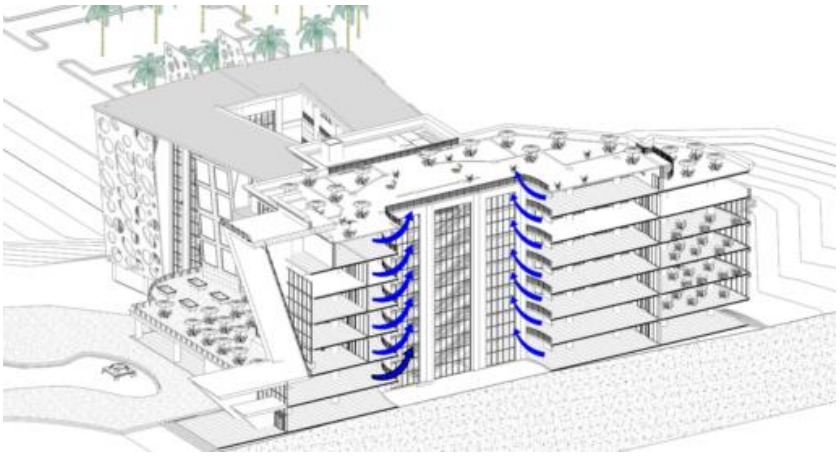


Figure 6.4 : **Encourage Natural ventilation**

Source: Author (2017)

- **Make use of natural light**

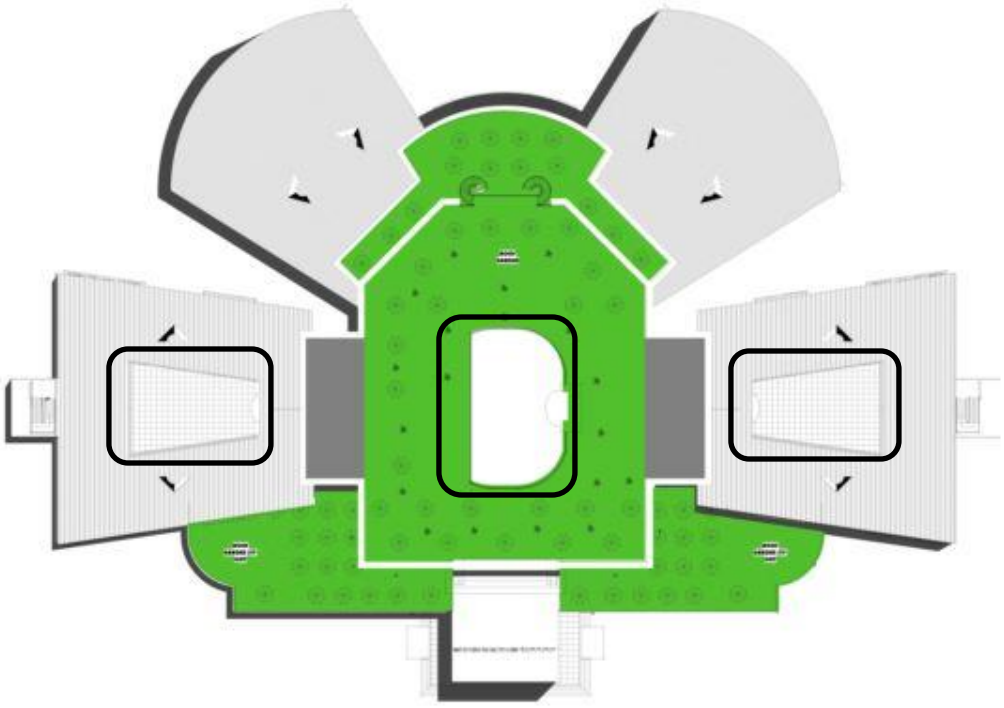


Figure 6.5: **Make use of natural light**

Source: Author (2017)

- **Create cool outdoor areas**

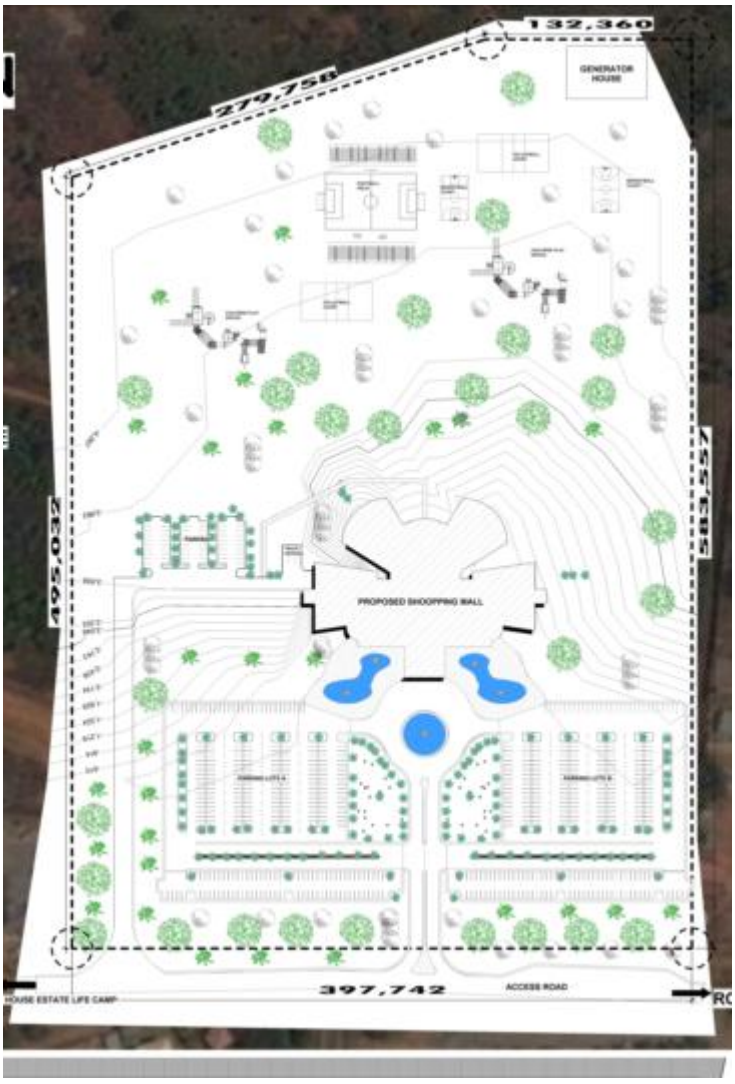


Figure 6.6: **Create cool outdoor area**

Source: Author (2017)

6.3 Sustainable Design Features

Various sustainable design features were adopted in order to achieve energy efficient building the figure 6.7 below shows all the strategies used for the design.

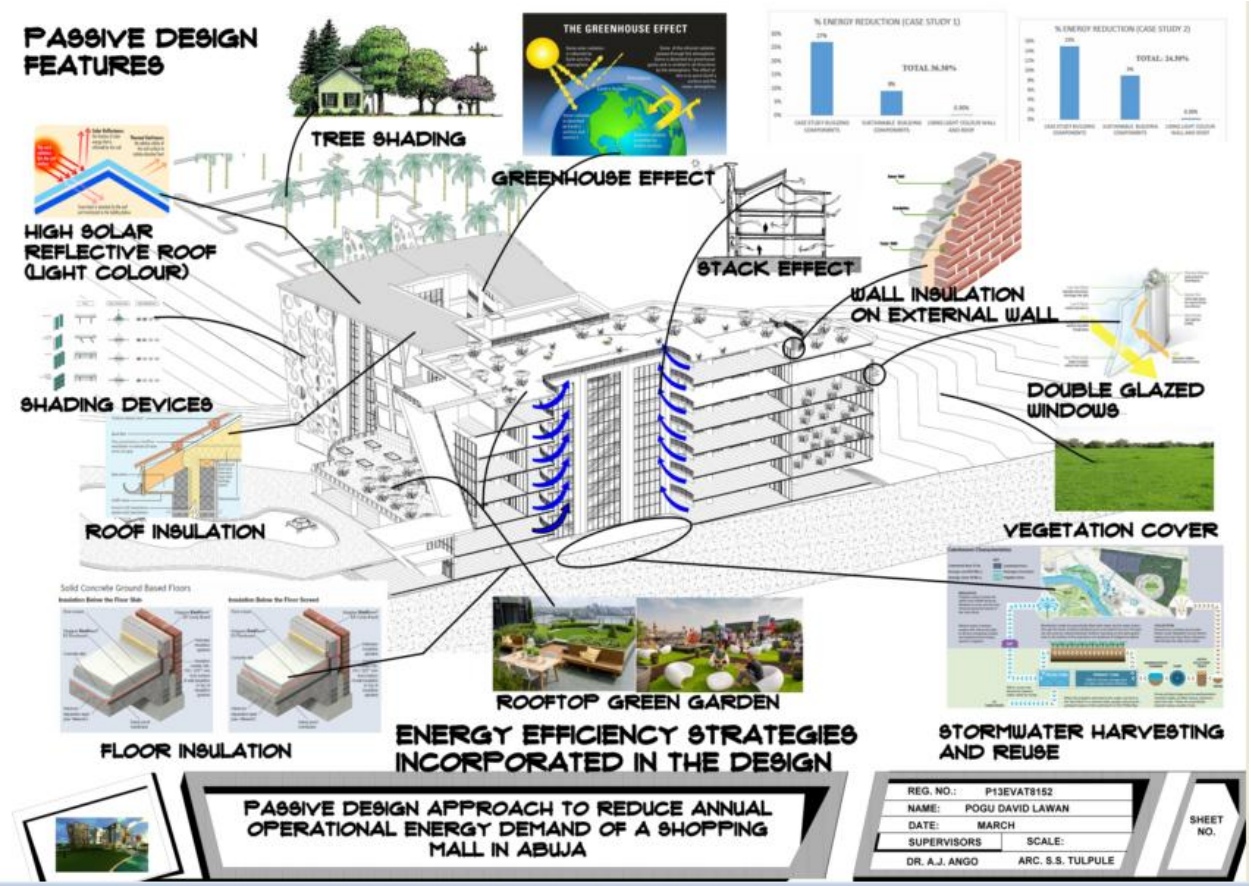


Figure 6.7: **Passive Design Feature**

Source: Author (2017)

6.4 Simulation Result of the Proposed Shopping Mall

6.4.1 Simulation procedure

The proposed shopping mall was design and modelled in revit 2011 and all the functional spaces were zoned both in area and volume and it was exported in form gbxml file format as shown on Figure 6.8.

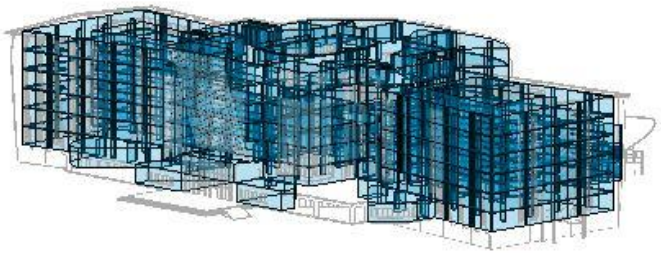


Figure 6.8: **gbxml file format from Autodesk Revit 2011**

Source: Ecotect (2011)

The gbxml file was then imported into the Ecotect analysis software and the weather data of Abuja was loaded. Figure 6.9 shows the daily sun path and the annual sun path within the Ecotect interface.

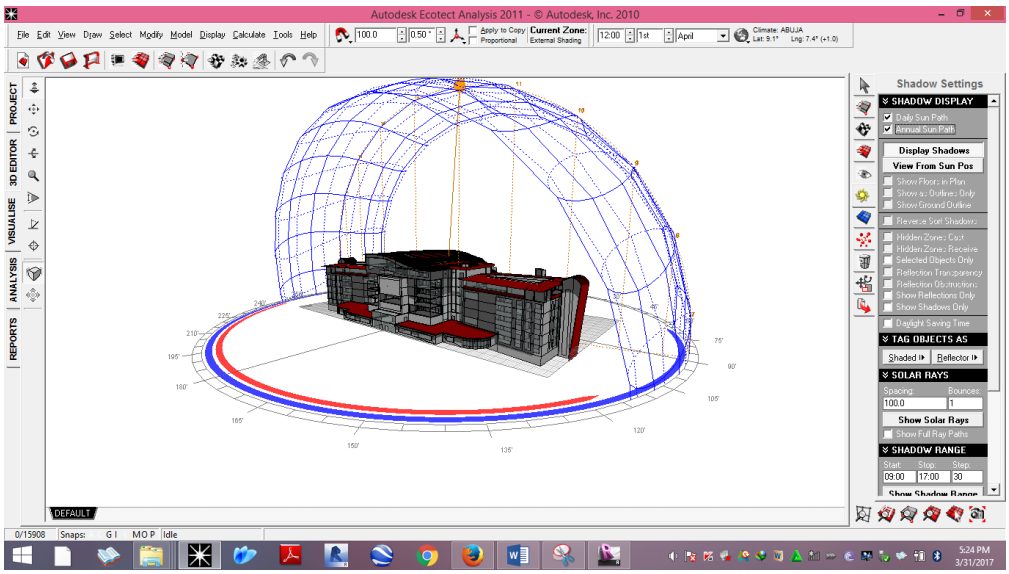


Figure 6.9: **Ecotect Analysis interface, uploaded with Abuja weather data**

Source: Ecotect (2011)

In conducting the analysis, a few assumptions related to the building zones were made. The building was divided into zones; Table 6.1a and 6.1b shows various essential assumptions

about each zone that were considered for calculating the energy consumption of the building. After considering all assumptions and conducting the analysis of energy consumption, a calculation was done to determine the amount of cooling energy required to keep the temperature of the building between 18^0C and 22^0C. The energy consumption was determined based on the case study building component as a design baseline. Finally, a set of higher-performance building component materials was recommended for the purpose of reducing the energy consumption of the building, as shown in Table 6.2 which led to the decrease in the annual energy consumption of the proposed shopping mall as shown in Tables 6.3 and 6.4. The graph showing the energy drop and percentage decrease are shown in Figures 6.10, 6.11, 6.12, 6.13 respectively.

Table 6.1 a: **Basic Assumption of the zones in the Analysis of Energy Consumption**

					THERMOSTAT RANGE		
FUNCTIONAL SPACE	**LIGHTING LEVEL**	**NO: PEOPLE**	**ACTIVITY**	**TYPE OF SYSTEM**	**LOWER BAND**	**UPPER BAND**	**HOURS OF OPERATION**
Shopping Area	900lux	5	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Hyper-market	900lux	70	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Cinema Hall	50lux	100	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-1:00AM
Basement	400lux	20	Walking 80w	Natural Ventilation	18^0C	22^0C	8:00AM-11:00PM
Stair case	50lux	15	Walking slow 115w	Natural Ventilation	18^0C	22^0C	8:00AM-11:00PM
Toilet	50lux	8	Resting 45w	Natural Ventilation	18^0C	22^0C	8:00AM-11:00PM

Table 6.1 b: **Basic Assumption of the zones in the Analysis of Energy Consumption**

					THERMOSTAT RANGE		
FUNCTIONAL SPACE	**LIGHTING LEVEL**	**NO: PEOPLE**	**ACTIVITY**	**TYPE OF SYSTEM**	**LOWER BAND**	**UPPER BAND**	**HOURS OF OPERATION**
Control Room	50lux	3	Walking slow 115w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Circulation Area	900lux	150	Walking slow 115w	Natural Ventilation	18^0C	22^0C	8:00AM-11:00PM
Office	400lux	3	Reading 55w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Amusement / Games and Bowling Section	600lux	20	Exercise 1100w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Pantry / Food Court	300lux	35	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM
Event Hall	300lux	150	Resting 45w	Full Air Conditioning	18^0C	22^0C	8:00AM-11:00PM

Source: Ecotect (2011)

Table 6.2: **Sustainable Building Components used in the Proposed Design**

SUSTAINABLE BUILDING COMPONENTS			
STRUCTURAL MEMBER	**MATERIAL**	**DESCRIPTION**	**U-VALUE**
WALL	MASONRY BRICK WALL	16'' BRICK CAVITY WALL WITH INSULATION	0.25w/m^2k
FLOOR	SOLID CONCRETE FLOOR SLAP	SOLID CONCRETE FLOOR SLAB FINISHED WITH THERMOPLASTIC TILES INSULATION	0.18w/m^2k
ROOF	ALLUMINIUM CORRUGATED ROOF	ALLUMINIUM CORRUGATED ROOF FINISHED WITH 12'' FIBERGLASS INSULATION	0.027w/m^2k
WINDOW	GLASS	DOUBLE GLAZED WINDOW WITH ALLUMINIUM FRAME	0.70w/m^2k
DOOR	WOODEN DOOR	1'' THICK WOODEN DOOR WITH TIMBER FRAME	0.64w/m^2k

Source: (Combustion Research Corporation, 2016), (kingspan insulation, 2016),

(Department of the Environment Building 2005, Regulation technical guidance document,

2005)

Table 6.3: **Monthly Heating / Cooling Load Comparison with Case Study 1**

Monthly Heating/Cooling Loads				
	CASE STUDY 1 (CEDDI PLAZA)	**CASE STUDY BUILDING COMPONENTS**	**SUSTAINABLE BUILDING COMPONENTS**	**USING LIGHT COLOUR WALL AND ROOF BUILDING COMPONENTS**
MONTH	**TOTAL ENERGY DEMAND (kWh)**	**TOTAL ENERGY DEMAND (kWh)**	**TOTAL ENERGY DEMAND (kWh)**	**TOTAL ENERGY DEMAND (kWh)**
Jan	127574.258	489220.781	443570.062	442675.781
Feb	136152.703	489179.094	441121.312	440078.031
Mar	161372.297	571725.438	513389.031	512065.5
Apr	139615.234	519544.781	470174.594	468849.062
May	129342.023	504907.375	460350.188	459021.5
Jun	108567.242	455721.156	419599.312	418238.906
Jul	102736.891	452152.219	416726.688	415438.062
Aug	102626.547	453040	418774.719	417373.125
Sep	95019.32	427273.219	395715.844	394420.094
Oct	117258.016	476273.719	435832.094	434590.938
Nov	112941.531	450742.281	409987.906	409165.875
Dec	117468.766	468114.781	425587.594	424755.469
TOTAL	**1450674.875**	**5757894.5**	**5250829.5**	**5236671.5**
PER M²	**192.497**	**140.085**	**127.749**	**127.404**
Floor Area:	**7536.083 m2**	**41102.750 m2**		
% Energy Reduction		27%	9%	0.30%
TOTAL ENERGY DROP	**36.30%**			

Source: Ecotect (2011)

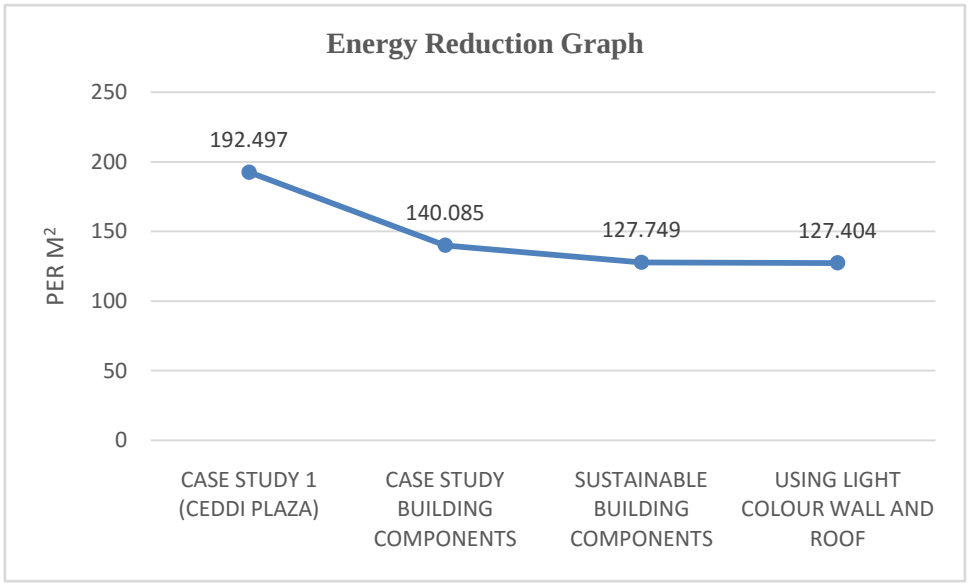


Figure 6.10: **Energy Reduction Graph with respect to Case Study 1**

Source: Author (2017)

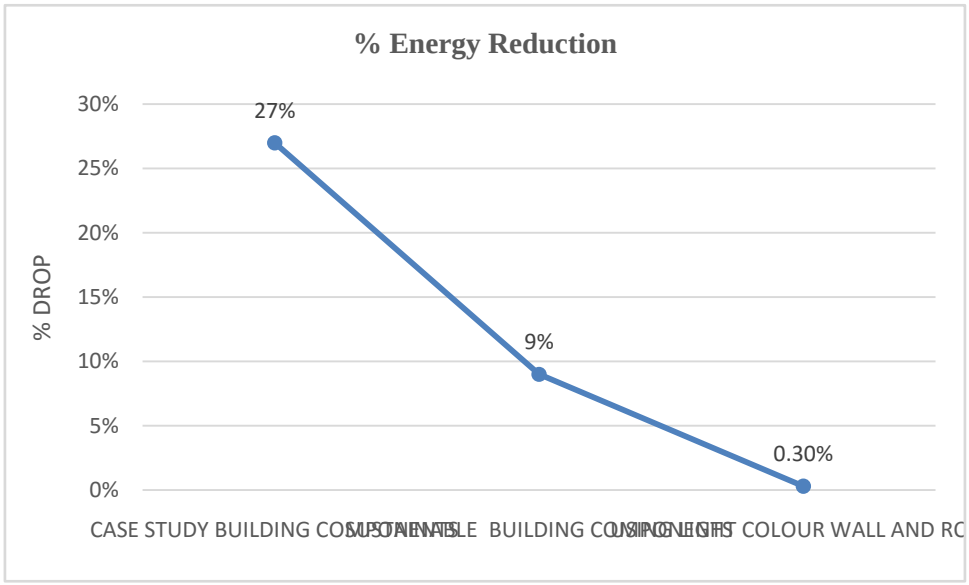


Figure 6.11: **Percentage of Energy Reduction with respect to Case Study 1**

Source: Author (2017)

Table 6.4: **Monthly Heating / Cooling Load Comparison with Case Study 2**

Monthly Total Energy Demand				
MONTH	**CASE STUDY 2 (SILVERBIRD) TOTAL ENERGY DEMAND (kWh)**	**CASE STUDY BUILDING COMPONENTS TOTAL ENERGY DEMAND (kWh)**	**SUSTAINABLE BUILDING COMPONENTS TOTAL ENERGY DEMAND (kWh)**	**USING LIGHT COLOUR WALL AND ROOF TOTAL ENERGY DEMAND (kWh)**
Jan	426001.219	489220.781	443570.062	442675.781
Feb	452451.656	489179.094	441121.312	440078.031
Mar	536288.188	571725.438	513389.031	512065.5
Apr	461655.531	519544.781	470174.594	468849.062
May	425635.656	504907.375	460350.188	459021.5
Jun	352604	455721.156	419599.312	418238.906
Jul	334173.188	452152.219	416726.688	415438.062
Aug	330767.219	453040	418774.719	417373.125
Sep	306816.469	427273.219	395715.844	394420.094
Oct	385199.375	476273.719	435832.094	434590.938
Nov	378815.531	450742.281	409987.906	409165.875
Dec	392789.969	468114.781	425587.594	424755.469
TOTAL	**4783198**	**5757894.5**	**5250829.5**	**5236671.5**
PER M²	**164.134**	**140.085**	**127.749**	**127.404**
Floor Area:	**29141.971 m2**	**41102.750 m2**		
% Energy Reduction		15%	9%	0.30%
TOTAL % DROP	**24.3%**			

Source: Ecotect (2011)

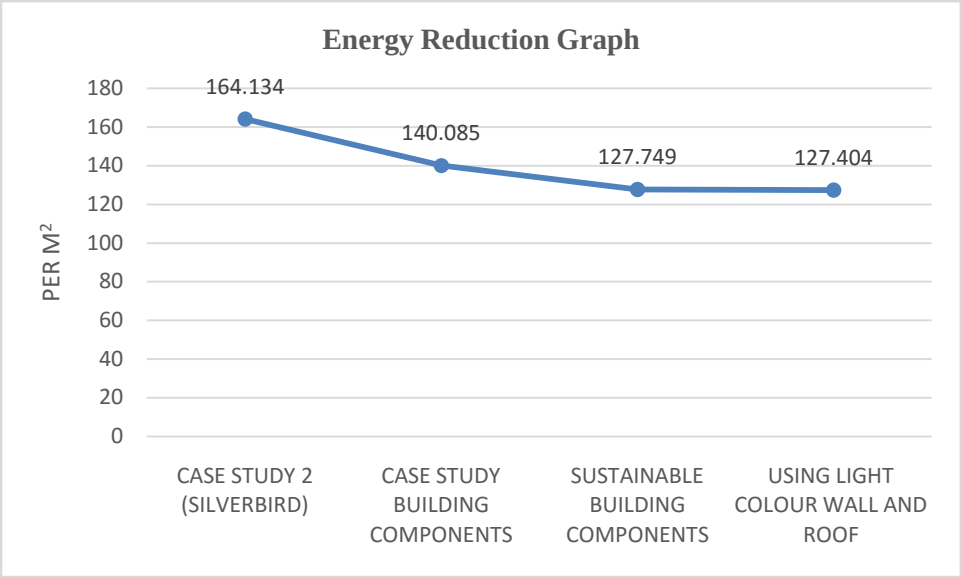


Figure 6.12: **Energy Reduction Graph with respect to Case Study 2**

Source: Author (2017)

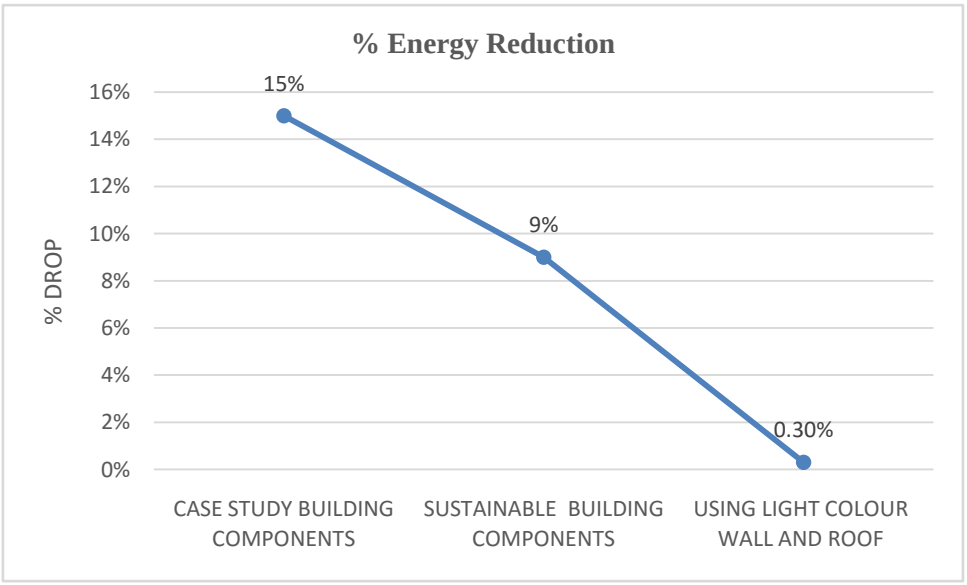


Figure 6.13: **Percentage of Energy Reduction with respect to Case Study 2**

Source: Author (2017)

CHAPTER SEVEN

SUMMARY OF FINDINGS, CONCLUSION, RECOMMENDATIONS, CONTRIBUTION TO KNOWLEDGE, AREAS OF FURTHER RESEARCH.

7.0 Summary of Findings

Buildings are responsible for at least 40% of energy used in most countries. In Nigeria construction activities has pervaded most urban centres as in the case of Abuja, buildings are design and build without considering the principles of passive design that will be peculiar to the local climate of the region. High internal temperatures in hot season and low in cold season are not only working against an efficient use of energy, but generate thermal shocks instead of providing opportunity for the human body to adapt. As for ventilation and air control, the uniform environments that shopping malls create throughout the year often do not correspond to the requirements of passive design. Air curtains located in the entrances, for example, work as a thermal shock instead of driving the user towards adaptive comfort. Therefore this research sought to develop a theoretical solution as well as design solution to reduce the annual operational energy demand of a shopping mall through passive design approach. The following methodologies were followed, all the 3 selected case studies were visited for a field survey, interviews were conducted photographs were taken, notes and sketches were collected. The research variables were draw from the theoretical frame work in the literature review in order to establish the basic passive design features and principles for designing a shopping mall in Abuja, Nigeria. The field survey involved a visual survey of all the passive design features employed on the case studied buildings. These passive design features were observed and analysed qualitatively using checklist. The field survey results shows that case studies 1, 2 & 3 has Fair, Average and

Poor application of passive design features respectively. Ceddi Plaza Abuja and Silverbird Entertainment Centre Abuja (i.e. Case study 1 and 2) were modelled and analysed with the aid of Autodesk Ecotect Analysis simulation software to determine the annual operational energy demand of the buildings. The simulation results show that case study 1 and 2 has a total annual operational energy consumption of 192.497kwh per square meter and 164.134kwh per square meter respectively; this result indicate that case 2 apply more passive design principles than case study 1. Furthermore, at the end of the research the proposed shopping was design, modelled and simulated and the results indicate a decrease in the annual operational energy demand by 36.3% and 24.3% with respects to case studies 1 and 2. Finally, building simulation and investigating the performance of the building virtually in the pre-construction stage will help architects and other consultants to apply suitable passive design principles that will suit a particular local climate and reduces the building annual operational energy.

7.1 Conclusion

This research sought to develop a theoretical solution as well as design solution to reduce the annual operational energy demand of a shopping mall through passive design approach. These were achieved through the following ways;

- Avoid heat gain into the building envelop by using sustainable building materials with low thermal mass and low-E glazing type windows.
- Encourage natural ventilation and avoid stack effect within the building, i.e. include open able windows and courtyard that enable the building to naturally ventilate and also prevent stack effect.

- Make use of natural light, by introducing courtyard and large double glazed windows to optimized natural lighting.
- Create cool outdoor area, through good landscaping to shade without blocking cooling breezes and use of plantings to reduce ground temperature and minimize reflected heat.

7.2 Recommendations

- Government should provide incentives for architects and other consultants to use the building simulation tool, specifically in the pre-construction stage, to investigate problems that are likely to occur in the future so that they can deal with such problems in the preliminary stage.
- On account of the global call for environmental consciousness and the knowledge of building construction impact on the natural fabric, research into the performance in the practice of sustainability ideas should be encouraged in developing countries. Focus should be on sustainable and innovative construction materials, low-carbon design techniques, renewable energy, waste and grey water recycling and other sustainable measures.
- The concept of passive design should be more prioritised at all levels of education (under-graduate and post graduate) in the Schools of Architecture especially in developing countries. This will strengthen the proper mentorship of environmentally-responsive architects. Consequently, the sustainable impact of architectural education will be reflected in the human habitat through the design and construction of passive buildings.

7.3 Contribution to Knowledge

- At the end of the research the proposed shopping design was simulated base on the assumptions established for zones in the analysis of energy consumption for case 1 and 2 and the various material properties used in the modelled building under observation were altered in terms their “u-values”, it was observed that the proposed shopping mall design indicate a decrease in the annual operational energy demand by 36.3% and 24.3% with respect to case study 1 and 2.
- This research revealed that, by only encouraging natural ventilation, allows buildings to naturally ventilate there by reduces heat gain and optimized natural light through the building fenestrations. This was achieved in the proposed design through the use of large courtyards and some open able windows and doors. The use of innovative construction materials, such as low thermal mass building components and low-E glazing types were also utilized.

7.4 Areas for Further Research

- This research is limited to only shopping malls within the dry-humid climate of Nigeria; other climatic zone can also be explore.
- This research is also limited to annual energy demand only at the operation phase of the building life cycle, other phases can also be explore(i.e. manufacturing phase, Transportation phase, on-site construction activities phase and demolition phase).

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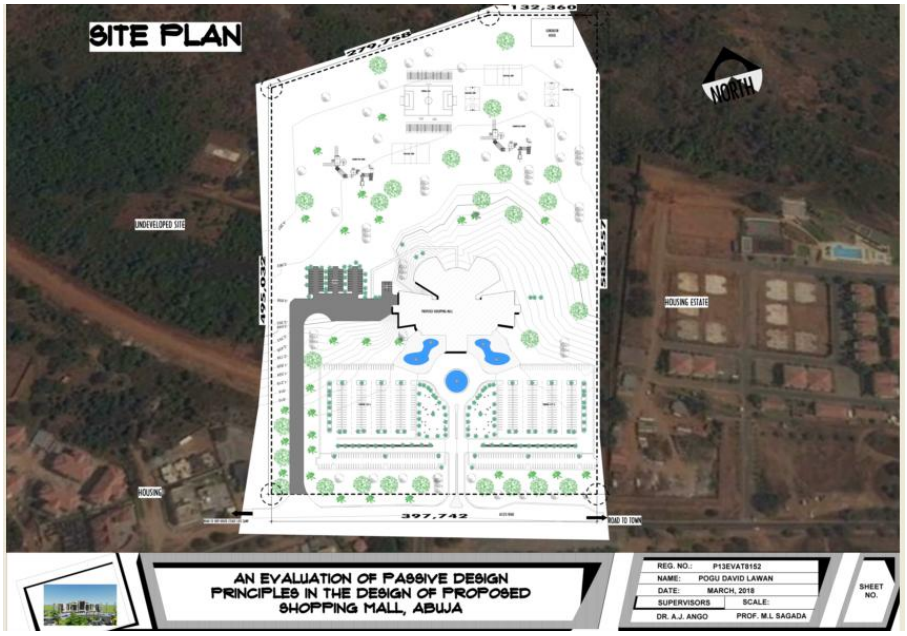
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APPENDICES

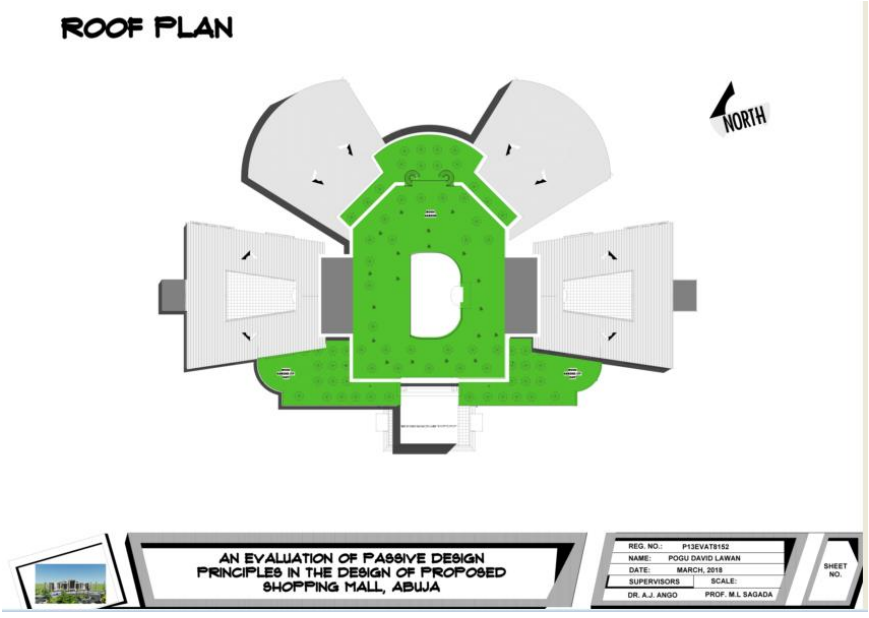
APPENDIX 'I'

Site plan of the proposed shopping mall



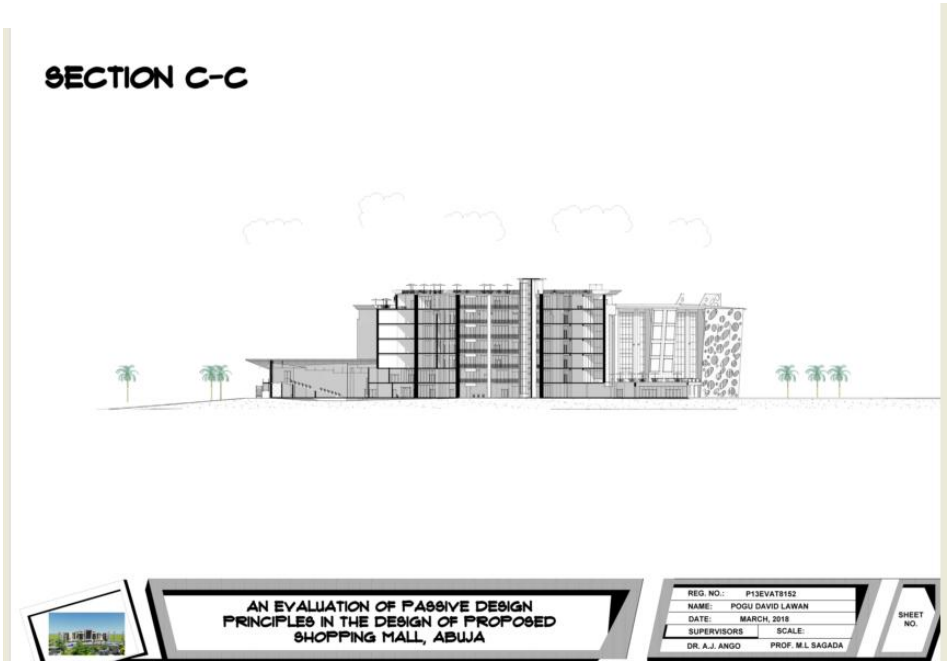
APPENDIX 'II'

Roof plan



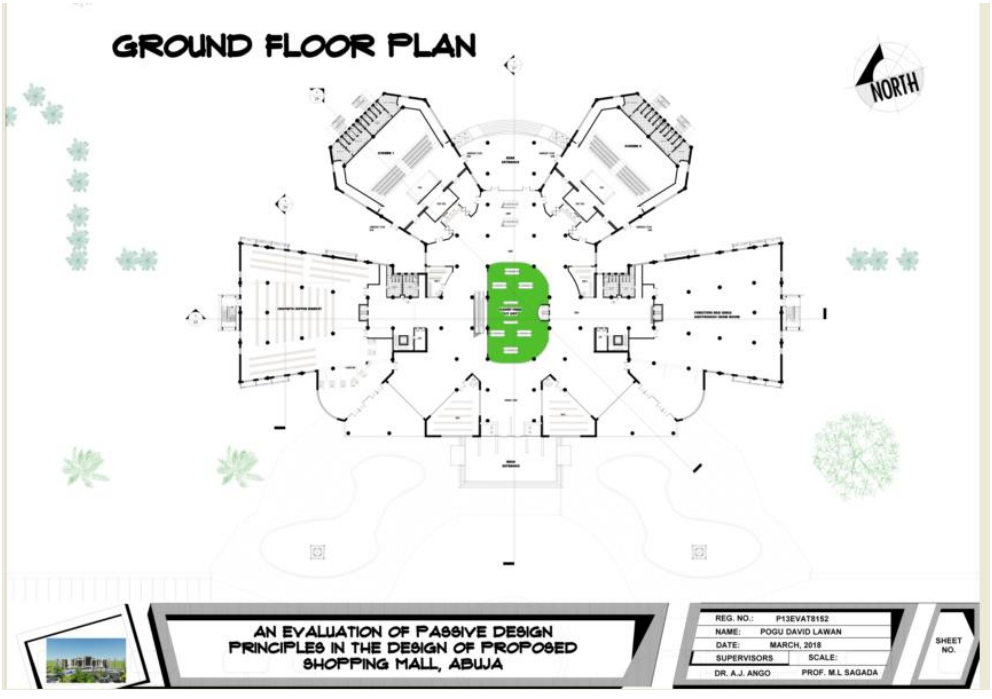
APPENDIX 'III'

Section C-C



APPENDIX 'IV'

Ground floor plan



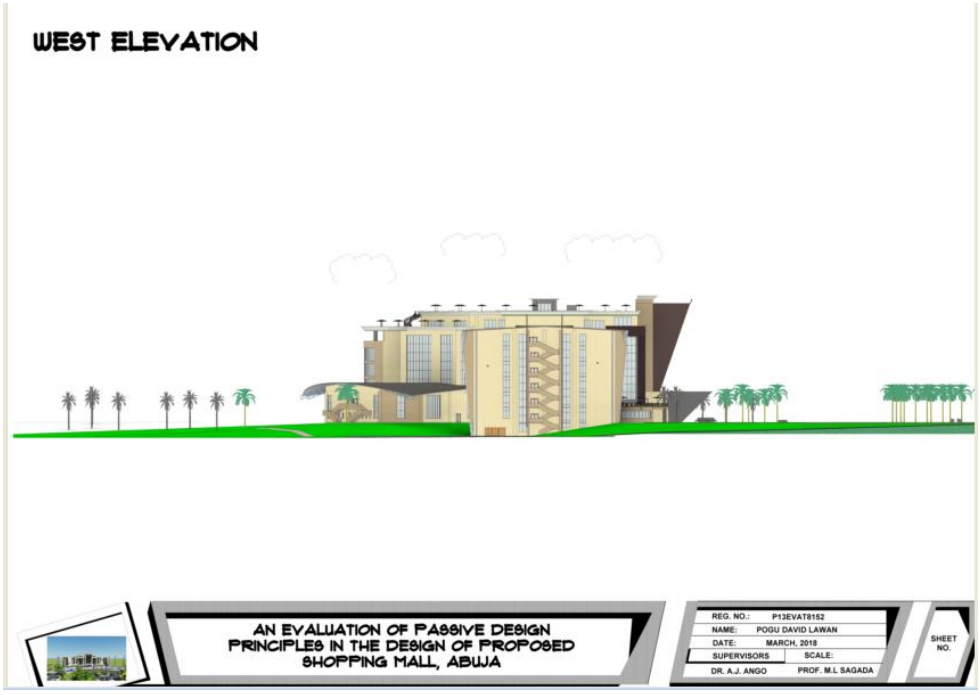
APPENDIX 'V'

South view



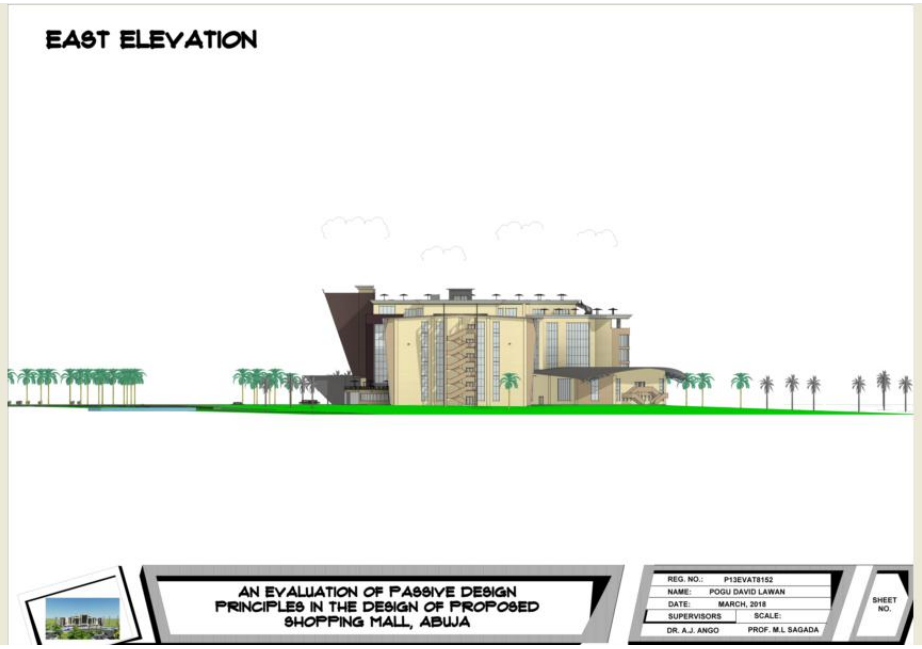
APPENDIX 'VI'

West view



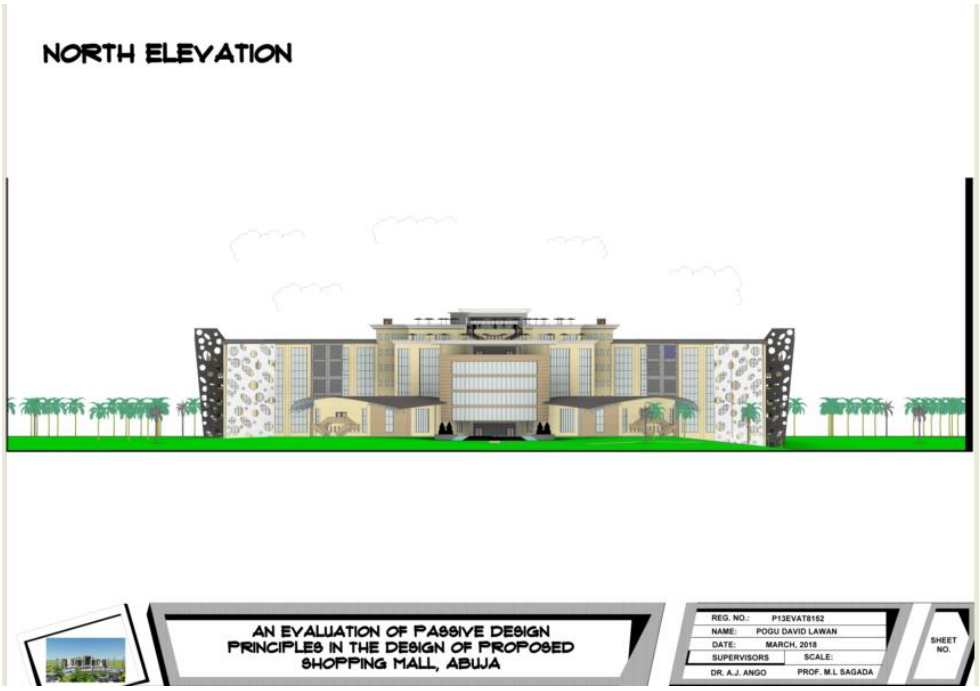
APPENDIX 'VII'

East view



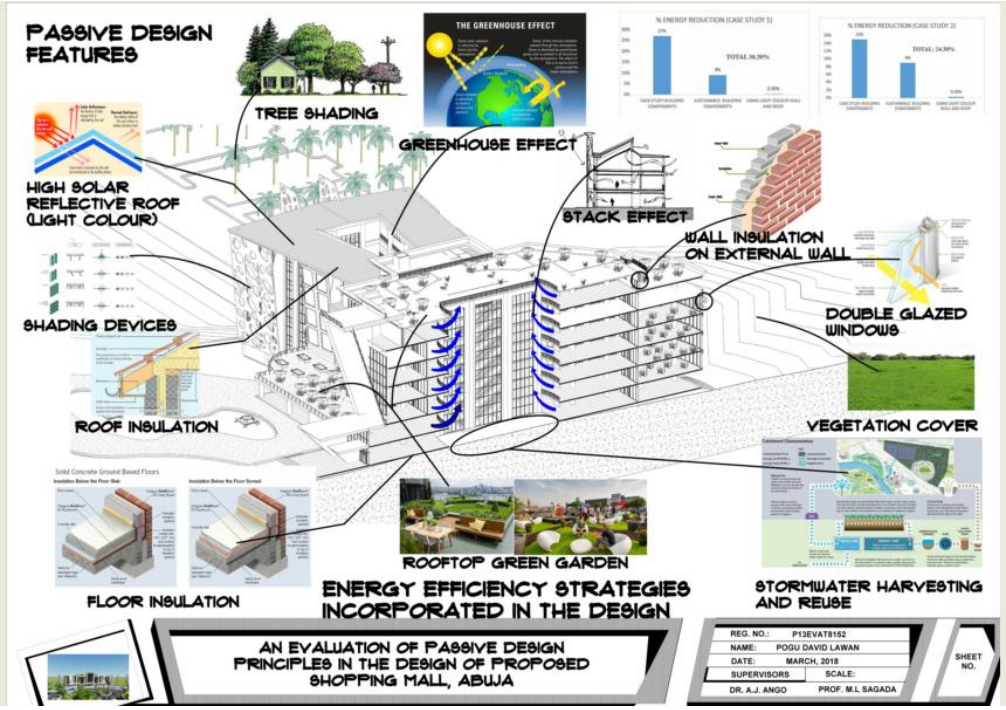
APPENDIX 'i'

North view



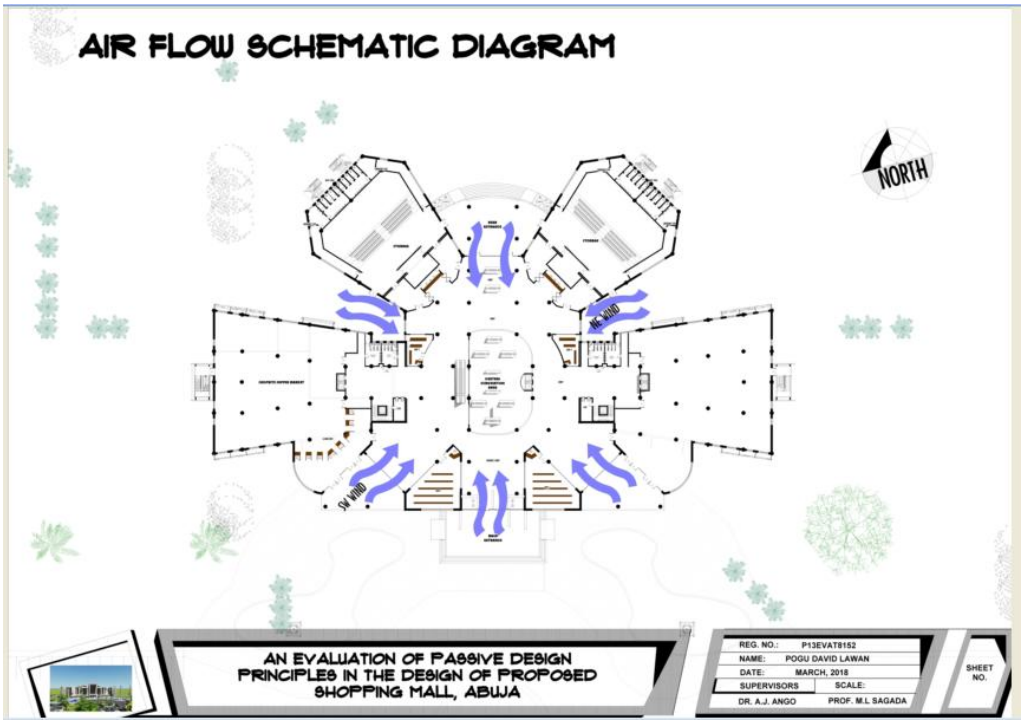
APPENDIX 'IX'

Passive design features and energy efficiency strategies



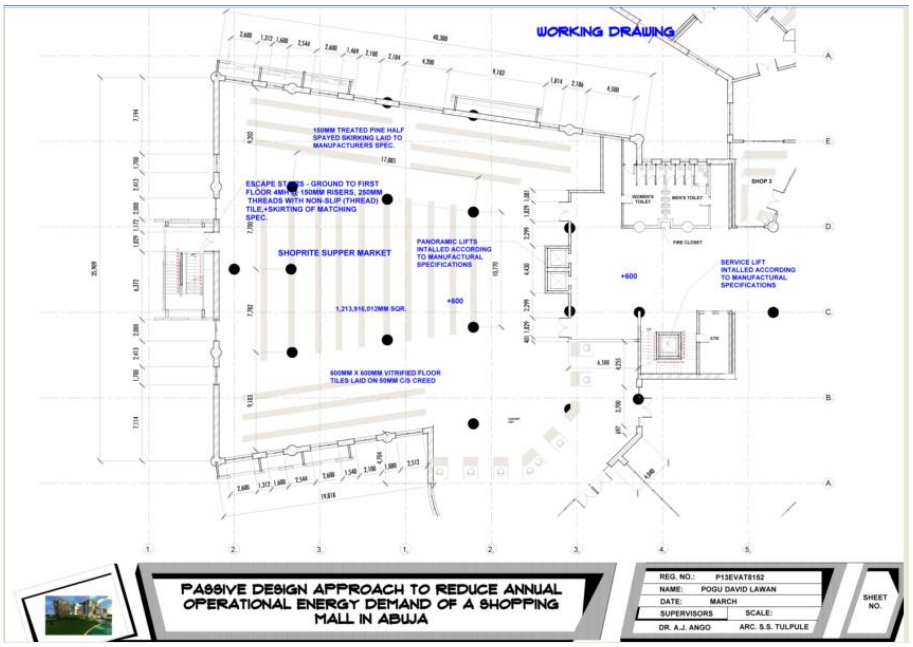
APPENDIX 'X'

Air flow schematic diagram



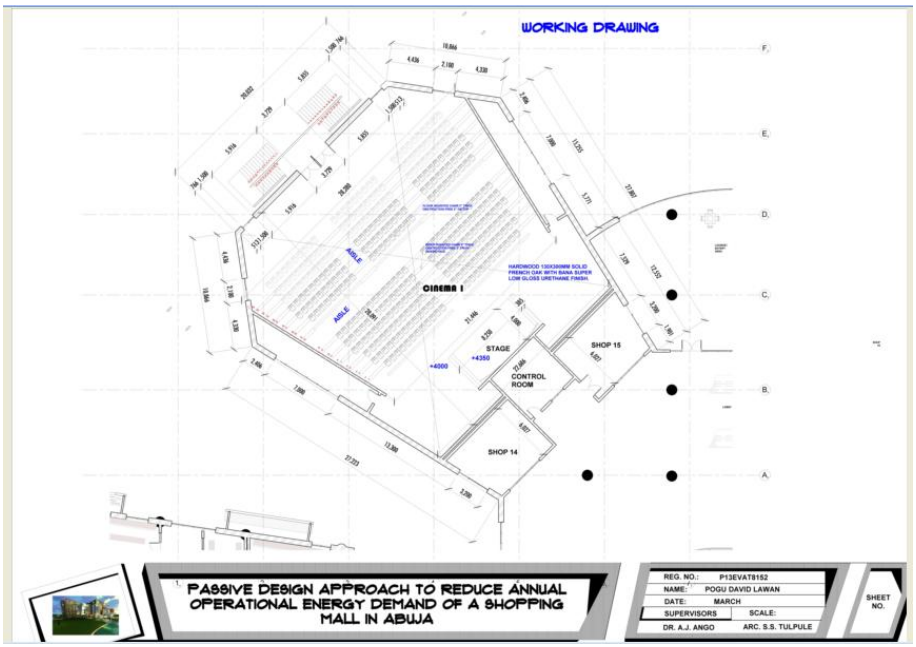
APPENDIX 'ii'

Working drawing hypermarket



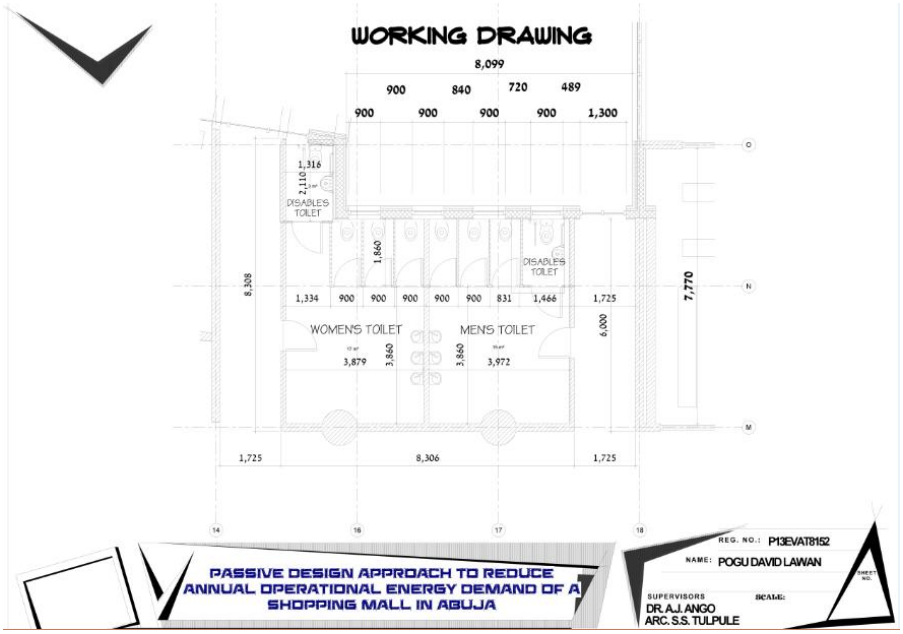
APPENDIX 'iii'

Working drawing cinema hall



APPENDIX iv

Working drawing toilet



APPENDIX 'v'

3D South view



APPENDIX ‘vi’

3D North view



APPENDIX ‘vii’

Cinema interior view



APPENDIX ‘ix’

3D view (1)



APPENDIX ‘viii’

3D view (2)

